

An Investigation of the Contribution of Cervical Factors to Headache

by

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Table of Contents

Chapter Title		Page
Declaration		i.
Authority of Access		i.
Abstract		ii.
Acknowledgments		v.
Chapter 1	The background to the study	1
	<i>Key Points</i>	37
Chapter 2	On conducting the study	38
	<i>Key Points</i>	71
Chapter 3	Method	73
	<i>Key Points</i>	118
Chapter Four	The results of the pilot study	119
	<i>Key Points</i>	125
Chapter Five	The results of the reproducibility study	126
	<i>Key Points</i>	148
Chapter Six	Headache: the outcome variable	150
	<i>Key Points</i>	169
Chapter Seven	Cervical resting posture: the putative cause of headache	171
	<i>Key Points</i>	197
Chapter Eight	The association between headache and cervical excursion angles	198
	<i>Key Points</i>	208
Chapter Nine	Other causes of headache	209
	<i>Key Points</i>	223

Chapter Ten	The association between frequent headache, C ₇ excursion angles and other causes of headache	225
	<i>Key Points</i>	238
Chapter Eleven	Further investigations into frequent headache and C ₇ excursion angles	239
	<i>Key Points</i>	245
Chapter Twelve	Discussion	246
Chapter Thirteen	Conclusion	275
References		a
Appendix 1	The results of preliminary testing	I
Appendix 2	The study documents	XIV
Appendix 3	The raw headache data	XXIX
Appendix 4	Papers published from this study	

Figures

Chapter		Caption	Page
Chapter 1	Figure 1.1	The headache symptom continuum	18
	Figure 1.2	Correct standing posture with respect to the Kendall et al (1952) reference points	24
	Figure 1.3	The cervical spine aligned with the vertical reference line of Kendall et al (1952).	25
	Figure 1.4	The arcs of movement traced during flexion/extension movement	28
	Figure 1.5	An illustration of the paradoxical translatory movement which occurs at C ₅₋₆	29
	Figure 1.6	Two specific head postures that have been described in the literature as 'Forward Head Posture'.	33
	Figure 1.7	The craniovertebral angle as measured from photographs	34
	Figure 1.8	'Total Head Excursion' concept	36
Chapter 2	Figure 2.1	The component measurements of cervical resting posture.	51
Chapter 3	Figure 3.1	The sets of study subjects and the role of each in the study	78
	Figure 3.2	The prevalence (main) study design	82
	Figure 3.3	The process of constructing the headache scale	84
	Figure 3.4	The two scoring methods of the nominal headache scale	86
	Figure 3.5	'Best case' results and the method of comparison of retrospective and prospective headache data (H/A = headache)	87
	Figure 3.6	The ordinaly-scored headache scale	88
	Figure 3.7	The plans for the Linear Excursion Measurement Device	91

	Figure 3.8	Measuring cervical excursion	94
	Figure 3.9a	The process of measuring a subject with large excursion angles occurring at both the helix and C ₇ .	95
	Figure 3.9b	The process of measuring a subject with small excursion angles occurring at both the helix and C ₇ .	96
	Figure 3.10	Measuring cervical short flexor endurance	105 / 6
Chapter 5	Figure 5.1	The movement of subjects between headache categories on consecutive months of testing	132 / 3
	Figure 5.2	An illustration of the Altman/ Bland plot for lateral flexion for men	143
	Figure 5.3	The Altman/ Bland plot for cervical short flexor endurance for both men and women	145
Chapter 6	Figure 6.1	The percentage of men and women with headache, compared with those with no headache	153
	Figure 6.2	The proportion of men and women who reported suffering occasional or frequent headache	154
	Figure 6.3	The odds ratios for subjects suffering stiff and aching necks	163
	Figure 6.4	The percentage of subjects with occasional and frequent headache reporting each category of headache management	167
Chapter 7	Figure 7.1	The strata in the excursion angle data examined in this section	175
	Figure 7.2	Habitual cervical resting posture associated with excursion angles in the first data division	177
	Figure 7.3	Habitual cervical resting posture associated with excursion angles in the second, third or fourth data divisions	178
	Figure 7.4	Habitual cervical resting posture associated with excursion angles in the fifth data division	179
	Figure 7.5	Plots describing the gender specific relationship between the excursion angles	182
	Figure 7.6	The proportion of men with occasional and frequent headache in each division of helix excursion angle data	186

	Figure 7.7	The proportion of women with occasional and frequent headache in each division of helix excursion angle data	187
	Figure 7.8	The odds ratios of occasional headache associated with the median value of four divisions of helix excursion angles.	186
	Figure 7.9	The odds ratio for occasional headache associated with the median value of four divisions of C_7 excursion angles.	187
	Figure 7.10	For men, the odds ratios for headache associated with the median value of four divisions of helix excursion angles.	189
	Figure 7.11	For women, the odds ratio for headache associated with the median value of four divisions of helix excursion angles	190
	Figure 7.12	The percentage of headache sufferers reporting a biomechanical activity precursor to headache.	196
Chapter 8	Figure 8.1	The odds ratios for frequent headache with C_7 excursion angles, modified by helix excursion angles	205 / 6
Chapter 9	Figure 9.1	The plot of the odds ratios of frequent headache associated with the median value of the divisions of neck circumference data	210
	Figure 9.2	The plot of the odds ratios for frequent headache associated with the median value of the divisions of the data for difference in front and back neck length	212
	Figure 9.3	The plot of the odds ratios for frequent headache associated with the median value of the divisions of the data for body mass index.	213
	Figure 9.4	The plot of the odds ratios for frequent headache associated with the median value of the divisions of mean lateral flexion range of movement.	216
	Figure 9.5	The plot of the odds ratios for frequent headache associated with the median value of the divisions of extension range of movement.	217 / 8
	Figure 9.6	The plot of the odds ratios for frequent headache	219

associated with the median value of the divisions of
cervical short flexor endurance capacity.

Chapter 11	Figure 11.1	The scoring sheet from the predictive model	243
Chapter 12	Figure 12.1	<i>Post hoc</i> Proposal 1 for the association between cervical resting posture (described by extreme cervical excursion angles), occasional and frequent headache	259
	Figure 12.2	<i>Post hoc</i> Proposal 2 for the association between cervical resting posture (measured by extreme cervical excursion angles), occasional and frequent headache	260

Tables

Chapter		Caption	Page
Chapter 3	Table 3.1	The loss of individuals to the study	78
	Table 3.2	Occupation codes used in the study	98
	Table 3.3	The number of subjects wearing categories of glasses	99
	Table 3.4	The types of dentures, and the numbers reporting each type	100
	Table 3.5	Components of the General Wellbeing Schedule	102
	Table 3.6	The correlation between measures of cervical muscle performance	107
Chapter 4	Table 4.1	The level of association between paired tests	120
	Table 4.2	The level of agreement between means	122
	Table 4.3	Random subject effects	123
Chapter 5	Table 5.1	Comparison between retrospective and prospective headache data	127
	Table 5.2	Comparison of retrospective and prospective headache data	129/30
	Table 5.3	Comparison of retrospective and prospective headache data	132
	Table 5.4	Consistency of reporting stiff and aching necks by headache subjects	134
	Table 5.5	The statistics demonstrating agreement between measurements of C ₇ excursion	136
	Table 5.6	The time effect on variability of C ₇ excursion	137
	Table 5.7	Comparing helix test and retest measurements	138
	Table 5.8	The time effect on variability of helix excursion	138
	Table 5.9	Agreement between measurements of anthropometric variables	140
	Table 5.10	The agreement between parametric functional measurements	142
	Table 5.11	Reproducibility of measurements of General Wellbeing	147

Chapter 6	Table 6.1	The risk estimates of headache for men and women	154
	Table 6.2	Functional and emotional measures	157/ 8
	Table 6.3	The results of <i>t</i> -tests between headache categories	159
	Table 6.4	Comparing measures within the frequent headache category	160
	Table 6.5	Percentage of headache sufferers reporting the remaining four pain criteria (Jull 1981)	162
	Table 6.6	Headache management methods	166
Chapter 7	Table 7.1	Frequency distribution statistics for excursion angles	172 / 3
	Table 7.2	Division of the C ₇ and helix excursion angle data into five parts	174
	Table 7.3	The linear association between excursion angles	184
Chapter 8	Table 8.1	The crude odds ratios of occasional headache with excursion angles	200
	Table 8.2	The crude odds ratios of frequent headache with excursion angles	200
	Table 8.3	The confounding effect of helix excursion on the model	204
	Table 8.4	The stratum odds ratios (upper and lower 95% CL) of frequent headache for C ₇ and helix	204
Chapter 9	Table 9.1	The odds ratios for frequent headache associated with categories of brassiere cup size	215
	Table 9.2	The odds ratios of frequent headache associated with categories of cervical flexor strength	220
	Table 9.3	The odds ratios of frequent headache associated with categories of cervical extensor strength	221
	Table 9.4	The odds ratios of headache in occupational groups	223
	Table 9.6	A summary of the points of division in the other causes of headache	224

Chapter 10	Table 10.1	Other causes of headache	226/ 7
	Table 10.2	Strata of C ₇ excursion and headache	234
	Table 10.3	Confounding effects of remaining variables	236
	Table 10.4	The confounding effect for women of relevant variables	237
Chapter 11	Table 11.1	The odds ratios of frequent headache with gender and C ₇ excursion angles	241
	Table 11.2	The parameter estimates from the model for frequent headache	243

Declaration

This Thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the Thesis, and to the best of the Candidate's knowledge and belief no material previously published or written by another person except where due acknowledgment is made in the text of the Thesis.

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Karen Grimmer

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Abstract

This thesis reports on the contribution of cervical factors to headache, which occurred in the absence of a history of trauma to the neck. Individuals who had never sustained an injury to the neck were randomly selected from the electoral rolls of two southern Tasmanian municipalities for this cross-sectional observational study. Five hundred and twenty-three individuals were invited to participate, and following exclusions and refusals, 490 subjects were examined. Twenty subjects participated in a pilot study of the device designed to measure cervical posture, 427 subjects participated in the main study, which examined the association between headache and habitual cervical resting posture in sitting, and 43 subjects supplied data on which the predictive model was tested.

New measures needed to be developed because no appropriate measures were available in a clinical setting. A diagnostic tool for headache was constructed from colloquial descriptions of three of the seven pain patterns attributed by Jull (1981) to headache of cervical origin. Non-diseased status was conferred upon those subjects who failed to identify all elements of the diagnostic tool. Headache frequency was measured retrospectively using a seven level nominal scale. Headache frequency in the study sample ranged from one headache every couple of months to daily. Cervical resting posture in sitting was measured by the Linear Excursion Measurement Device (LEMD), as the excursion of the superior-most tip of the helix of the ear (an anatomical point chosen to represent the distal aspect of the cervical spine) and the spinous process of C₇ (a point chosen to represent the proximal aspect of the cervical spine), when subjects moved from a standard corrected posture to their habitual resting posture.

All 427 subjects participating in the main study were asked to recall the frequency of their headaches in the preceding month. A subset of these subjects (93 subjects) also supplied prospective headache data by completing a headache diary for a month. A comparison of retrospective and prospective data indicated that, over a two month period, the headache characteristic was stable and consistent. Compared with the prospective headache diary, men tended to over-report headache retrospectively while women tended to under-report it.

Headache was expressed in frequencies of occasional and frequent: occasional headache occurred less frequently than twice per month, and frequent headache occurred at least twice a month. The prevalence in the sample data, of headache specifically associated with cervical factors, was 63.7 per cent. Occasional headache was suffered by 55.5 per cent of headache sufferers and frequent headaches were suffered by the remaining 44.5 per cent of headache sufferers. Significantly more women reported headache than men.

The excursion of the two chosen anatomical points was reproducible over days, and over a month. Angles of excursion of 11.5 degrees or more, traced by the spinous process of C₇, were associated with frequent headache. The crude odds ratios (C.O.R.) were similar for men and women (2.29 (95%CL 1.03-5.01) and 2.43 (95%CL 1.00-5.81) respectively). Angles of excursion of 6 degrees or more, traced by the superior-most tip of the helix of the ear, were associated with frequent headache for men but not for women (C.O.R. of 1.73 (95%CL 0.86-3.49) and 1.06 (95%CL 0.52-2.14) respectively). There was no convincing association between occasional headache and large angles of excursion at the spinous process of C₇ and the superior-most tip of the helix of the ear, for either men or women.

The cervical resting posture described by large angles of excursion of the superior-most tip of the helix of the ear, and of the spinous process of C₇ was characterised by a forward leading chin with the occiput of the skull caudally rotated within, or slightly anterior to, the vertical axis. The cervical lordosis was habitually extended in this resting head position.

In order to inform future studies on headache, and to control for confounding effects on the association between frequent headache and cervical excursion angles, a number of other causes of headache were proposed and measured. There was little biological theory to guide these investigations. Two scenarios were proposed to more clearly define the nature of the relationship of headache with its causes. One scenario was proposed where causes of headache were associated in an antecedent fashion with cervical resting posture during postural development, and during moment-by-moment postural manoeuvres. The second scenario described the independent action of selected variables with headache, acting on established posture.

There were gender differences in estimates of the strength of association, between headache, cervical resting posture and the other proposed causes of headache. The cross-sectional nature of the data precluded more specific examination of these relationships. Under the scenario of independence of action with headache, wearing dentures confounded the association between C₇ excursion angles and frequent headache for men but not for women. A predictive model for frequent headache was developed. It included only the dummy predictor for C₇ excursion angles, as no other variable was identified as an important inclusion. This model predicted frequent headache with moderate sensitivity and fair specificity, but predicted less well in an independent data set.

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Chapter One

The background to the study

'When you're lying awake with a dismal headache,
and repose is taboo'd by anxiety,
I conceive you may use any language you choose
to indulge in, without impropriety.'
- Gilbert and Sullivan, *Iolanthe* (1882)

This thesis reports on a study that was conducted on a random sample of never-injured individuals. The study aimed to determine the prevalence of headache specifically associated with cervical factors, and to investigate cervical resting posture as a cause of headache.

This chapter presents background material to the study. In Section 1.1, the reasons for undertaking the study are described, and the study aims are listed. Relevant literature on headache and cervical posture is reviewed in Sections 1.2 and 1.3.

1.1 The development of the study

1.1.1 The rationale

The need for this study became apparent to me during an experience in court in 1989, when I acted as an expert witness in a personal injury case. The case involved a middle-aged man who claimed to have sustained a 'whiplash' injury to the neck in a motor vehicle accident. His symptoms consisted mainly of frequent headaches. Descriptions of his headaches matched descriptions of headache considered to be of cervical aetiology (Jull 1981, 1985, 1986, Pfaffenrath et al 1987, Sjaastad et al 1983). In the court, I was asked to explain the mechanisms of a 'whiplash' injury to the cervical spine, to anticipate the claimant's long term prognosis, and to compare the frequency of his headaches with those of a similar aetiology that were experienced by an uninjured man of the same age. There was a considerable body of research from which to seek answers to the first and second questions (McKinney 1989, McKinney et al 1989, McNab 1969, 1971, 1973, Mealey et al 1986, Mendelson 1982, Newland 1988, Norris and Watt 1983). I was unable to answer the third question however, because of the paucity of knowledge regarding the prevalence and causes of headache. It was the third question that motivated me to embark on this study.

1.1.2 The aims of the study

This study investigated a sample of never-injured individuals in order to:

- establish the prevalence of headache specifically associated with cervical factors; and
- investigate cervical resting posture as a cause of headache.

Physiotherapists are frequently consulted by individuals with headache (Jull 1988, Trott 1988). In order to ensure that the findings were relevant to physiotherapists in clinical practice, the study factors were measured in a manner that was appropriate to a clinical setting.

1.2 A review of the literature on headache

Headache is one of the earliest recorded medical complaints (Black 1788 cited in Waters 1986). While benign headache remains one of the most common ailments for which medical practitioners are consulted (Dalessio 1987), universal agreement has not been reached on its prevalence, classification, causes and treatment (Edmeads 1978, 1988, Marcus 1992, Oleson 1991, Rapoport 1992, Silberstein 1992). This lack of agreement is particularly evident in the case of headache that is specifically associated with cervical factors.

It has long been recognised that cervical factors can be associated with headache (Lance 1982 citing Hilton 1860-1862). Edmeads (1988) lists three conditions that he considers must apply for headache to be of cervical aetiology:

- '(1) there should be pain sensitive structures within the neck;
- (2) there should be identifiable pathologic processes or physiologic dysfunctions within the neck capable of serving as an adequate stimulus to the pain receptors in the cervical structures;
- (3) there should be identifiable neurologic pathways and mechanisms through which pain originating in the cervical segments may be referred to the head' (p. 1874).

Edmeads' conditions provided a rational framework within which to review the clinical findings and anecdotal evidence contained in the headache literature.

1.2.1 Pain sensitive cervical structures

A number of structures in the cervical spine have been described as pain sensitive, including the intervertebral disc, the zygapophyseal joint, the capsule and the surrounding structures of muscle, ligament, blood vessels and nerve tissue (Bogduk 1981, Bogduk et al 1985, Bogduk and Marsland 1986, 1988, Gurumoorthy 1991, Schonstrom et al 1993, White and Panjabi 1990, Worth 1988). This satisfies the first of Edmeads' conditions (1988) for headache to be of cervical aetiology. A large number of cervical structures are reported to be innervated by the upper three cervical nerves (Davies 1972).

The nerve root of C_1 has sensory input to the deep occipital tissues, the occipital muscles, the atlanto-occipital and the atlanto-axial joint, the paramedian dura of the posterior cranial fossa and the prevertebral muscles.

The nerve root of C_2 supplies the skin of the occiput, the cervical short flexor muscles, the atlanto-axial joint, the prevertebral muscles, sternocleidomastoid, upper fibres of trapezius and the walls of the posterior cranial fossa.

The nerve root of C_3 supplies cervical short flexors, the skin of the subocciput, zygapophyseal joint of C_{2-3} , the prevertebral muscles and sternocleidomastoid and trapezius. It branches medially to become the third occipital nerve and the greater occipital nerve. Fibres of the trigeminal nerve have been shown to extend in some subjects to the level of C_3 , accounting for headache pain being reported in the forehead and periorbital regions (Bogduk 1987, 1989).

1.2.2 Neurologic pathways

Neurological pathways that are considered to specifically refer pain from the cervical spine to the head have been clearly described under experimental conditions (Bogduk 1981, Bogduk and Marsland 1986, 1988, Kerr 1961, Kimmel 1961). In research conducted earlier this century, a distinctive headache was produced by artificial stimulation of those parts of the midbrain which had connections to the upper cervical nerve roots (Campbell and Parsons 1944, Cyriax 1934, Feinstein et al 1954, Kerr 1961, Kerr and Olafson 1961, Kimmel 1961, Northfield 1938, Penfield and McNaughton 1940). Reports were also recorded at this time of a similar type of headache associated with degenerative conditions of the upper cervical spine (Bland et al 1963, Bland 1967, Hunter and Mayfield 1949, Schultz and Semmes 1950, Trevor-Jones 1964). It was subsequently identified that in all instances nociceptive impulses were transmitted to the midbrain from the cervical spine via the cells of the substantia gelatinosa and the spinal nucleus of the trigeminal nerve, and to the spinal dura mater by branches of the spinal meningeal rami passing through the posterior cranial fossa (Carpenter 1976, Denny Brown and Yanagisawa 1973, Kimmel 1961, Taren and Kahn 1962).

Bogduk and his colleagues confirmed and clarified these findings in more recent work (Bogduk 1981, Bogduk et al 1981, Bogduk et al 1985, Bogduk and Marsland 1986, 1988, Bogduk 1989). These researchers demonstrated that the trigemino-cervical nucleus, comprising the spinal nucleus of the trigeminal nerve, the nerve roots of the upper cervical spine and the substantia gelatinosa, was responsible for innervating all somatic structures of the head and the upper neck, as well as mediating pain transmissions to the midbrain. Evidence of specific neural pathways to which cervical pain mediation is attributed satisfies the third of Edmeads' conditions (1988) for headache to be of cervical aetiology.

1.2.3 Pathological processes in the cervical spine

The debate regarding the cervical nature of headache focuses on the second of Edmeads' (1988) conditions, that which relates to 'identifiable pathological processes and/ or physiologic dysfunctions in the cervical spine' (p.1874). It is commonly agreed that disease processes in the cervical spine are causal agents of headache (Bland 1967, Cabot and Becker 1978, Fournier and Rathelot 1960, Robinson 1966, Sharp and Purser 1961, Stevens et al 1971). Consensus has not been reached however, on the influence on headache of dysfunctional¹ cervical structures in the absence of disease (Bogduk 1987, 1989, Edeling 1982, Lance 1982, Jull 1988).

1.2.3.1 Diseases of the cervical spine

Diseases of the cervical spine include the effects of trauma, congenital abnormalities, degenerative processes and/ or infection (Edmeads 1988). As this present study investigated headache in never-injured individuals, this section focuses on diseases other than trauma. Degenerative changes to cervical structures, such as those resulting from osteoarthritis, rheumatoid arthritis and ankylosing spondylitis, are widely accepted causes of headache (Bland 1967, Bland et al 1963, Cabot and Becker 1978, Fournier and Rathelot 1960, Robinson 1966, Sharp and Purser 1961, Stevens et al 1971). The pathophysiology associated with these conditions includes histological changes to the bony surfaces of vertebrae as well as to the surrounding soft tissue structures. This can lead to irritation and/ or entrapment of local nerve roots (Bland et al 1963, Braaf and Rosner 1965, Trevor-Jones 1964).

1. The word 'function' is defined as 'the mode of action by which a physical organ fulfils its purpose' (The Shorter Oxford Dictionary 1973, p.817). The prefix 'dys' is defined in the same dictionary as 'destroying the good sense of the word, or emphasising the bad' (p. 621). The word 'dysfunction' refers in this present study to less than "normal" performance of cervical structures.

Congenital bony abnormalities such as atlanto-axial dislocation and separation of the odontoid or occipitalisation of the atlas have been observed in some individuals with headache (McRae 1968). Bogduk (1981) and Silberstein (1992) suggest that while the bony anomaly itself may be painless, the surrounding soft tissue structures are placed at a mechanical disadvantage, which can result in headache. Mechanical irritation of specific cervical nerve roots has also been identified as a cause of headache, in particular occipital nerve neuralgia (Dugan et al 1962, Hartsock 1940) and accessory nerve neuroma (Cherington and Hendee 1978).

1.2.3.2 Dysfunction of structures of the cervical spine

There is common agreement that in the absence of disease, cervical structures can become dysfunctional when placed under sufficient physiological load (Basmajian 1979, Bogduk 1989, Janda 1980, 1988, Jull 1985, Panjabi 1974, Sahrmann 1987, Trott 1988). The lack of agreement on the causal role of dysfunctional cervical structures in headache focuses on the validity of tools that are currently used to identify sites of dysfunction. For instance, there is debate on:

- the sensitivity of radiological investigations in identifying dysfunctional cervical structures (Bogduk 1981, Bogduk et al 1985, Jull 1981) or confirming perceived dysfunctional cervical structures as causes of headache (Montalbetti et al 1992, Pfaffenrath et al 1987);
- the placebo effect of analgesic blocks to the dysfunctional cervical structure considered to be implicated in the headache mechanism (Bogduk and Marsland 1986, 1988, Edmeads 1978, 1988); and
- the efficacy of manual therapy examination of the cervical spine (Berger and Gerstenbrand 1986, Jull 1981, Ng 1980) in detecting dysfunctional cervical structures (Bogduk 1987, Edmeads 1988).

1.2.3 Headache prevalence

Headache considered to be of a cervical aetiology has been studied only in self-selected individuals (Bogduk and Marsland 1986, 1988, Bovim and Sand 1992, Jull 1981, 1985, Pfaffenrath et al 1987, Sjaastad et al 1983). It is not possible to measure prevalence by studying only the numerator population. The individuals in these studies all suffered from a long history of headache, were in present pain and were enrolled for research purposes when they presented for medical, dental, chiropractic and/or physiotherapeutic treatment for their condition. In the absence of population-based studies specifically on headache associated with cervical factors, prevalence studies of headache of any aetiology formed the basis for sample size calculation for the purpose of this present study.

Hult conducted benchmarked studies into specific occupational activities and neck/ shoulder pain in 1954, and reported that headache associated with neck pain was suffered by 18-20 per cent of the working population. More recent population-based studies, that differentiated only between migrainous and non-migrainous headaches using the International Headache Society criteria, reported prevalence of non-migrainous headache between 30 and 50 per cent (Bastos et al 1993, de Benedettis and Lorenzetti 1992, Edmeads et al 1993, Honkasalo et al 1993, Jensen et al 1993, Kaganov et al 1981, Munoz et al 1993, Pryse-Phillips et al 1992, Thomson et al 1993).

In these studies, women were reported as suffering more frequent headaches than men. Reasons for gender differences in prevalence of headache of any aetiology are not well described.

1.2.4 Diagnostic tools

Various diagnostic methods are currently used in an attempt to identify the specific site in the cervical spine that is believed to be the causal agent of headache. This section evaluates the usefulness of each diagnostic method to identify headache in a population-based study on never-injured individuals.

1.2.4.1 Nerve blocks

A cervical aetiology for headache has been assumed following a decrease in headache, immediately after infiltration of specific cervical structures with analgesic nerve blocks (Bogduk 1981, 1989, Bogduk and Marsland 1986, 1988, Bovim and Sand 1992, Sjaastad et al 1983, Pfaffenrath et al 1987). The placebo effect of the nerve block however, has not been discounted (Edmeads 1988). There are several drawbacks to the use of analgesic blocks in identifying a cervical mechanism for headache, in a study on never-injured individuals.

- The use of diagnostic blocks is appropriate only for subjects in present pain, where a diagnosis is made on the result of the intervention. Only a percentage of the population will be symptomatic at the time of assessment;
- The specific cervical structure that is considered to be the causal agent of headache must be accurately identified before it is injected²;
- Diagnostic blocks are expensive and invasive;
- Diagnostic blocks are not available in the majority of clinical physiotherapy settings.

². Refer to Sections 1.2.4.2 and 1.2.4.5 on the use of X-rays and manual examination in the diagnosis of dysfunctional cervical structures.

1.2.4.2 Radiological evidence

X-rays are considered useful in describing the extent of injury to the cervical spine, if they are employed immediately following the injury (Weir 1975, Wholey et al 1958). Cervical joint dysfunction however, is not categorically confirmed by radiological evidence (Bogduk 1981, Bogduk et al 1985, Jull 1981), and evidence of cervical degeneration has not been strongly correlated with headache occurrence (Montalbetti et al 1992, Pfaffenrath et al 1987). While X-rays identify visible gross degenerative changes in cervical joints (Penning 1968), they confirm neither dysfunctional cervical structures nor causes of headache. Radiological investigations are inappropriate to diagnose headache in a population-based study on never-injured individuals because:

- they are expensive;
- they infringe personal safety; and
- they are not sufficiently sensitive in identifying dysfunctional cervical structures or categorically associating them with headache.

1.2.4.3 Pain distribution

Pain distribution has been widely discussed as a method of headache diagnosis and classification. While early headache research reported that specific types of headache were represented by specific pain patterns (Ad Hoc Committee on Classification of Headache 1962), there are recent reports that similar symptoms occur in headaches that are considered to be of different aetiologies (Marcus 1992, Merikangas et al 1993, Rapoport 1992, Raskin and Appenzeller 1980, Sheftell 1992, Silberstein 1992). The pain distribution attributed to headache specifically associated with cervical factors (Jull 1981, Pfaffenrath et al 1987, Sjaastad 1987) contains symptoms that have been attributed to tension-type, and to migraine headache. It is now commonly agreed that pain distribution alone is insufficient evidence upon which to classify headache, or to determine its aetiology (Marcus 1992, Oleson 1988, Silberstein 1992).

1.2.4.4 Secondary pain behaviour

It has been reported that symptoms secondarily associated with the causal agent of headache are useful diagnostic indicators (Silberstein 1992). Symptoms associated with the cervical spine have been employed to identify headache associated with the same cervical structures (Aprill et al 1990, Centonze et al 1992, Dwyer et al 1990, Hasvold and Johnsen 1993, Pfaffenrath et al 1987, Sjaastad et al 1983, Sjaastad 1987, Weiss 1993). These include crepitation, pain and restriction in neck movements and neck/ shoulder/ arm symptoms. Specifically, headache associated with the cervical spine is frequently reported on waking from 'awkward nocturnal positioning of the head' (Sjaastad 1987 p. 402). This pain behaviour differs from that reported in tension-type headache studies, where pain generally begins during the day, or after stress, and is relieved by sleep (Lance 1982, Sheftell 1992, Silberstein 1992).

Autonomic symptoms associated with irritable upper cervical nerve roots have been reported by sufferers of chronic headache specifically associated with the cervical spine (Jull 1981, Pfaffenrath et al 1987, Sjaastad 1987). These symptoms include nausea, dizziness, lacrymation, facial flush, tinnitus, and eyelid oedema. However, autonomic symptoms have also been reported by sufferers of headache of other aetiologies (Oleson 1991), and thus may not be specific to cervical influences.

1.2.4.5 Manual therapy techniques

The use of manual therapy techniques has been promoted by physiotherapists as essential when diagnosing and treating headache. These beliefs are based on the premise that less than 'normal' function of cervical structures is a causal agent of headache, and that manual therapy techniques can detect, and then address, less than 'normal' function (Jull 1981). Successful manual therapy intervention is believed to effect a decrease in symptoms (Gaughwin 1988, Jones 1991, Jull 1981, 1985, Maitland 1973, 1979). There is a widely held belief among physiotherapists that headache pain, reproduced by mobilising a cervical structure, is evidence of specific cervical dysfunction (Jull 1981, 1985, 1988). Such claims have advanced the concept of a primary headache specifically of cervical aetiology particularly within the physiotherapy profession (Edeling 1982, 1988, Jull 1981, 1986, 1988).

One Australian physiotherapist (Gwendolyn Jull) has tested her manipulative therapy skills by evaluating her findings against those of radiologically controlled infiltration of analgesic blocks to structures of the cervical spine (Bogduk 1987, Jull 1985). Perfect agreement was reported in each of the chronic headache cases examined ($n=12$), where the particular segmental level of the cervical spine involved in each subject's headache was identified both by Jull (using manual therapy techniques) and by Bogduk (using analgesic blocks). Similar tests by other manipulative physiotherapists have not been reported, and therefore it has yet to be established that all manipulative therapists have skills equal to those of Gwendolyn Jull (Bogduk 1987). Moreover, the validity of manual therapy examination in establishing specific dysfunction of spinal joints has not been demonstrated and claims that manual therapy techniques move spinal joints cannot be substantiated (Bogduk 1987, Edmeads 1988).

1.2.4.6 The behaviour of headache symptoms

In an effort to describe headache specifically associated with cervical factors, Jull compiled a list of clinical findings and common symptoms reported by patients attending her physiotherapy clinic for treatment for chronic cervical problems. This list was first reported in the proceedings of the Australian Manipulative Physiotherapist's Conference in 1981. It was published internationally after further testing (Jull 1985, 1986). Jull's list includes the distribution, presentation and behaviour of headache pain, the events secondarily associated with headache and the findings of manual therapy examination. It was the most comprehensive set of descriptors of headache associated with cervical factors found in the literature search. Jull's list is reported, with the pain criteria noted in italics.

- '1. *The headache can affect any area of the head or face. It may be unilateral or bilateral.*
2. *Occipital or neck pain is a frequent accompaniment of headache.*
3. *The headache is commonly described as an ache of moderate severity, or as a feeling of tightness or heaviness in the head.*
4. *Headache is frequently accompanied by vascular or autonomic symptoms.*
5. *Patients commonly wake with headache.*
6. *Headache is usually associated with sustained neck postures, tension or neck pain and movement.*
7. *There is frequently a prolonged history of headache.*
8. Neck trauma is commonly reported.
9. Standard X-rays usually display no abnormality.
10. Upper cervical joint signs are present.' (Jull 1981, p.42).

All reference to this list in this thesis is attributed to Jull's original presentation in 1981.

Considered individually, five of the pain criteria in Jull's list (1981) (Criteria One, Two, Three, Four and Seven) are non specific to headache associated with cervical factors. Criteria One and Three describe pain symptoms attributed to migrainous and non-migrainous headache (Ad Hoc Committee on Classification of Headache 1962, Oleson 1988). Symptoms of migrainous and non-migrainous headache are now considered to overlap and are commonly described as occupying the left hand aspect of the continuum of headache symptoms³ (Marcus 1992, Silberstein 1992). Occipital or neck pain accompanying headache (Criterion Two), autonomic symptoms (Criterion Four) and a prolonged history of headache (Criterion Seven) have also been reported by individuals with migraine or tension-type headache (Lance 1982, Kaganov et al 1981, Rasmussen 1992, Silberstein 1992) or headache from secondary factors such as disease or spinal injection (Oleson 1988, Silberstein 1992, Tomsak 1991).

The remaining two pain criteria (Five and Six), have been described by others as being attributed specifically to the influence of cervical factors on headache (Bovim and Sand 1992, Centonze et al 1992, Hasvold and Johnsen 1993, Pfaffenrath et al 1987, Sjaastad et al 1983, Sjaastad 1987, Weiss 1993). The specific underlying cervical influence on a headache on waking has already been noted (Sjaastad et al 1983), and neck pain following sustained head-on-neck posture is considered to implicate cervical structures which have been embarrassed by the sustained postural activity (Basmajian 1979, Cailliet 1989, Saunders 1982).

³. The headache continuum is discussed in Section 1.2.6 of this chapter.

1.2.5 Headache classification

This section reports on the various classifications that have been afforded to headache associated specifically with cervical factors. Debate on classification relates to the second of Edmeads conditions for cervical origin headache, that is 'identifiable pathologic processes or physiologic dysfunctions within the neck capable of serving as an adequate stimulus to the pain receptors in the cervical structures' (Edmeads 1988, p 1874).

1.2.5.1 Secondary headache

A secondary classification is assigned to headache on the assumption that there is an identifiable primary condition from which headache results. When there is intervention for the primary condition, the secondary (headache) symptoms are modified (Centonze et al 1992, Weiss 1993). Headache has been reported as a symptom secondary to cervical spondylosis (Lance 1982) and poor cervical resting posture (Jull 1988). A secondary classification for headache specifically associated with cervical factors is plausible on the grounds that while the structures of the cervical spine are rich in nerve endings (Gurumoorthy 1991, Schonstrom et al 1993), they should not be a source of pain under 'normal' circumstances (Basmajian 1979, Salminen 1984, Wägenhausen 1971).

1.2.5.2 Primary headache

Headache associated with cervical factors has been described as a distinct primary headache with a specific identifiable causal agency sited in the cervical spine (Bogduk 1981, 1988, Bovim and Sand 1992, Hasvold and Johnsen 1993, Jull 1986, Sjaastad et al 1983). Causal agents have been proposed as identifiable disease processes as well as cervical structures that are dysfunctional in the absence of disease (Bogduk et al 1985, Edeling 1982, 1988, Hasvold and Johnsen 1993, Janes and Hooshmand 1965, Jull 1981, Pfaffenrath et al 1987, Puce 1964, Sjaastad 1987).

1.2.5.3 Classification as a sub category of another primary headache type

There is no agreement on the classification of headache associated with cervical factors. Even supporters of a separate primary classification for such headache question whether 'the present headache (cervicogenic) group (may) be mixed up with other, accepted headache entities, as a consequence of overemphasising or under emphasising certain headache characteristics in the diagnostic process?' (Fredericksen et al 1987, p. 156). Moreover, Bogduk (1987) concedes that 'there are no clinical features by which cervical headaches can be distinguished from what might otherwise be construed as common headache or tension headache' (p. 166).

It has been suggested that headache associated with cervical factors should be sub-classified as a tension-type headache (Lance 1978, Stevens 1993) or alternatively, as a manifestation of migraine headache (Edmeads 1988, 1990).

Sub classification as a tension-type headache was based on the premise that cervical dysfunction is manifested as 'abnormal' cervical muscle activity (Lance 1978), which has been a traditionally accepted cause of tension-type headache (Ad Hoc Committee on Classification of Headache 1962, Bakal and Kaganov 1979, Dalessio 1987, Pawl 1977). Painful trigger points and excessive muscle contraction have been identified in the upper neck muscles of individuals who complain of headache, and who also exhibit degenerative changes to the cervical spine (Lance 1982, Pfaffenrath and Isler 1993, Trevor-Jones 1964). Noxious stimulation of the upper three cervical nerve roots (Bogduk 1981, Kerr 1961, Kimmel 1961) plausibly underlies 'abnormal' cervical muscle activity (Edmeads 1988), as the C₂ and C₃ nerve roots supply the cervical extensor muscles which are commonly affected by 'abnormal' muscle contraction (Elkind 1987, Lance 1978, Trott 1988).

Recent studies suggest that excessive muscle contraction is not solely associated with tension-type headache (Silberstein 1992), as individuals with common migraine demonstrate excessive amounts of cervical muscle activity (Oleson 1978, Featherstone 1985). Moreover, variable correlations have been reported between cervical muscle contraction and headache (Oleson 1991).

A sub classification of common migraine headache (Edmeads 1988) has been proposed because similarities have been observed in symptoms attributed to headache specifically associated with cervical factors, and descriptions attributed to common migraine headache (Edmeads 1988, Fredericksen et al 1987, Oleson 1978, 1988, Pfaffenrath et al 1987, Sjaastad et al 1983, Waters 1974b). Common symptoms include unilaterality of pain, nausea, phonophotophobia, type of pain and recurrence of headache (Edmeads 1988).

Over the last few years, it has become more common to consider primary benign headache as a continuum, ranging from non-migrainous to classic migraine headache (Oleson 1988, Marcus 1992, Raskin and Appenzeller 1980, Sheftell 1992, Silberstein 1992). The benign recurring headache continuum, based on descriptions by Silberstein (1992), Marcus (1992) and Sheftell (1992), is represented in Figure 1.1. The headache continuum facilitates the concept of overlapping symptoms of headache and the complex inter-twining of headache aetiologies. It offers a method of classifying headache according to the presentation of individual sufferer's symptoms.

tension-type	common migraine	classic migraine
mild, nondescript pain	mild/ moderate throbbing pain	localised severe throbbing pain
rare vomiting		prominent vomiting
rare neurological symptoms		focal neurological symptoms

Figure 1.1. The headache symptom continuum

1.2.6 Measurement of headache

Headache has been measured and reported in terms of intensity and/ or frequency (Edeling 1982, 1988, Lance 1982, Melzack 1975, Merskey 1984, 1986).

1.2.6.1 Pain quality

Recent population-based studies using questionnaires, assessed headache quality in graded nominal categories that combined descriptions of intensity with measures of frequency (Merikangas et al 1993, Munoz et al 1993, Pryse-Phillips et al 1993). The validity of these descriptors of pain quality, and their suitability for population-based studies, are untested.

1.2.6.2 Headache intensity only

Measurements of headache intensity are commonly used when assessing the outcome of intervention on an individual basis (Cole et al 1994, Lance 1978, Oleson 1988). Pain intensity has been measured by line scales, colour circles, body diagrams, word lists, and amount and type of medication (Edeling 1988, Jacox 1987, Melzack 1975, Merskey 1984). Variability in reporting pain intensity limits its usefulness in population-based studies (Melzack 1975).

1.2.6.3 Headache frequency only

Population-based studies on headache have largely measured headache frequency because this concept is logical and commonly understood and therefore has face validity (Andrasik and Holroyd 1980, Carmines and Zeller 1979, Kaganov et al 1981, Rothstein 1985, Thompson and Collins 1979, Waters and O'Connor 1970).

1.2.6.3.1 Line scales

In studies on tension-type headache (Kaganov et al 1981, Bakal and Kaganov 1979, Thompson et al 1980), and a report of management of headache associated with cervical factors (Edeling 1988), subjects were asked to rate headache frequency on a five point line scale. Frequent headache corresponded with a rating to the right hand of the scale. Line scales are not commonly used to measure frequency in population-based studies because one cannot be certain that line scales mean the same thing to all individuals (Merskey 1984).

1.2.6.3.2 A numeric value

The frequency of headache has been reported in periods of time, such as hours of pain and/ or frequency of pain episodes within a time period (Bovim and Sand 1992, Dalessio 1984, Elkind 1987, Jull 1986, Lance 1982, Pfaffenrath et al 1987, Sjaastad 1987). There is no uniformity in time-based recording, particularly of chronic headache. For instance, Edeling (1988), Jull (1986, 1988) and Watson and Trott (1991, 1993) described chronic cervical origin headache as two or more headaches per month occurring for the last six months, while Kaganov et al (1981) and Stevens (1993) defined chronic, tension-type headache as that occurring at least fifteen days a month for the past six months.

1.2.6.3.3 Categories of headache frequency

Both migrainous and non-migrainous headache have been described as occurring in episodic (or occasional) form and chronic⁴ (or frequent) forms (Anderson and Franks 1981, Kaganov et al 1981, Martin and Mathews 1978, Mathew et al 1982, Saper 1986). Symptoms of occasional and frequent headache are considered to differ in quantity, not quality. Kaganov et al (1981) proposed the concept of the severity model of headache, where the chronic tension-type headache disorder reflected two interwoven processes: '.....failure to cope with less severe headaches, accompanied by an increasing involvement and automaticity of the underlying psychological and physiological processes' (p. 157).

1.2.6.4 The frequency of headache specifically associated with cervical factors

To date, studies on headache specifically associated with cervical factors have been conducted only on self selected subjects reporting frequent headaches. No information has been provided on an occasional headache presentation, or on the morbidity of headache in never-injured individuals.

⁴. Chronic pain is defined as that which lasts for six months or more, and which regularly affects the sufferer's lifestyle, mental attitude and physical expectations (IASP Subcommittee Report 1979, NH and MRC Report 1988).

1.2.6.5 Chronic daily headache

It has been recently proposed that the chronic daily headache is a separate primary headache type, combining pathophysiologies associated with several headache aetiologies into a separate headache entity (Martin et al 1993, Pfaffenrath and Isler 1993, Sheftell 1992, Solomon et al 1992). A deficiency in mono-amine transmitters in the Central Nervous System is considered to play a part in chronic recurrent headache, where local chemical changes sensitise end-organs to pain stimuli (Rolfe et al 1977, Sicuteri 1977, Silberstein 1992), and complex interacting factors are involved in the headache mechanism (Edmeads 1990, Merskey 1984, Sheftell 1992, Sternbach 1974). These authors consider that the IHS Criteria (Olesen 1988) deals inadequately with the classification of the chronic daily headache.

1.2.7 Summary

A diagnosis of headache of cervical aetiology is considered appropriate when headache occurs in the presence of identifiable disease processes in the cervical spine. Disease processes include the effect of trauma on the cervical spine. There is continuing debate regarding the diagnosis and classification of headache when the causal agency is considered to be cervical dysfunction occurring in the absence of disease. There is no standard approach to the measurement of the intensity and frequency of headache, and nothing is known regarding the prevalence of headache specifically associated with cervical factors in the never-injured population.

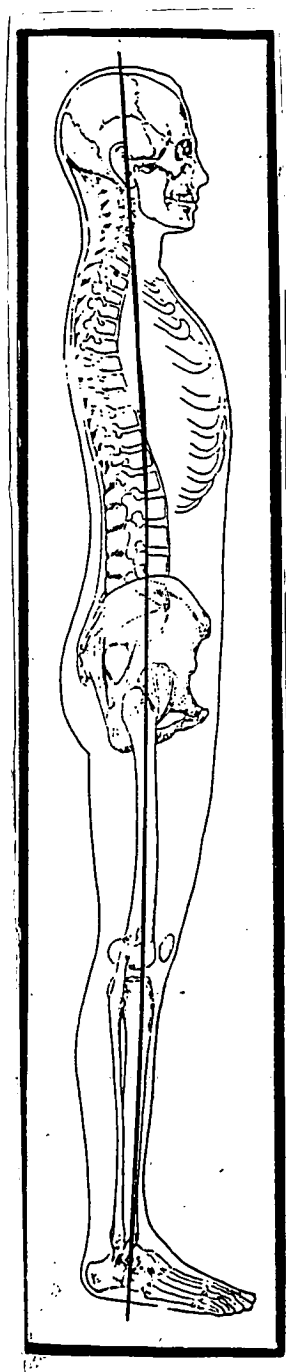
1.3 Cervical resting posture

One cause of headache is considered to be poor cervical resting posture (Abrahams 1977, Centonze et al 1992, Dunsker et al 1978, Edeling 1982, 1986, Janda 1980, 1988, Jull 1986, Kendall et al 1952, Lewit 1971, McKenzie 1990, Weiss 1993). A function of the cervical spine is to counterbalance the head against the force of gravity (Janda 1988, Kendall et al 1952, Wägenhausen 1971). Poor head posture is considered to be inefficient in that it increases the antigravity load on cervical structures and instigates dysfunctional physiological processes (Deng and Goldsmith 1987, Janda 1988, Jensen et al 1993, Trott 1988, Worth 1988). Jull (1986) noted that headache, similar to that reported by individuals with a 'whiplash' injury to the cervical spine, is reported by some individuals who have never sustained such an injury. In these circumstances, she made the claim that headache resulted from 'undetected accumulation of microtrauma, postural and functional strain when no injury is recalled' (p. 327).

The relationship between headache and cervical resting posture is not well defined (Edmeads 1988), as no strong association has been demonstrated with any one particular habitual cervical resting posture. Evidence to specifically associate particular cervical resting postures with pain has been provided largely by single case studies in which correction of perceived poor posture by realigning the position of the head with respect to the gravitational line (Kendall et al 1952) has effected a decrease in headache and neck pain (Ayub et al 1984, Bibby and Preston 1981, Jull 1986, Rocabardo 1983, Trott 1988).

The analysis of human posture has long been of interest to researchers in a number of medical disciplines. Posture is defined by The Shorter Oxford Dictionary (1973) as 'the relative disposition of anything the position and carriage of the limbs and the body as a whole' (p. 1639). Such was the interest in the relevance of human posture to a number of areas of health that a committee of the American Academy of Orthopaedic Surgery was specially convened in 1947 for the purpose of discussing it. This committee defined good posture as 'that state of muscular and skeletal balance that protects the supporting structures of the body against injury or progressive deformity irrespective of attitude (erect, lying, squatting, stooping) in which these structures are working or resting. Under such conditions the muscles will function most efficiently and the optimum positions are afforded to the thoracic and abdominal organs. Poor posture is a faulty relationship of the various parts of the body that produces increased strain on the supporting structures and in which there is less efficient balance of the body over its base of support' (reported by Sahrman (1988)).

It is most common to assess erect human posture in the sagittal plane using a vertical reference line, as in this view the body's response to gravitational forces is well observed (Wägenhausen 1971). The most commonly cited vertical reference line, that of Kendall et al (1952), is a compromise between the actual gravitational line which was reported by Hall et al (1986), and the plumb line which was used originally by Braune and Fischer (1889). In the sagittal view Kendall et al (1952) considered that their vertical reference line divided the body into anterior and posterior components which were hypothetically of equal weight. An illustration of the human body aligned with the Kendall et al (1952) reference line is provided in Figure 1.2. The anatomical reference points through which the line passes are listed.



Slightly posterior to the coronal suture
 Through the external auditory meatus
 Through the dens or odontoid process of the axis
 Through the bodies of the cervical vertebrae

Through the bodies of the lumbar vertebrae
 Through the sacral promontory
 Slightly posterior to the centre of the hip joint

Slightly anterior to the centre of the knee joint

Slightly anterior to the lateral malleolus
 Through the calcaneo-cuboid joint

Figure 1.2. Correct standing posture with respect to the Kendall et al (1952) reference points

The human spine aligned against a vertical reference in the sagittal plane forms three curves, the posteriorly concave aspects of which are described as the cervical and lumbar lordoses (Kendall et al 1952, Turner 1956). These spinal curves are a compensatory arrangement of spinal segments that support the body with minimal stress and energy expenditure (Apley 1977, Basmajian 1979, Cyriax 1978, Hutchins 1966, Lindh 1980, Penning 1988, Rasch and Burke 1978, Sahrmann 1987, 1988, Smidt et al 1984). Figure 1.3 provides a view of the most efficient arrangement of the cervical spine in the sagittal plane with reference to the vertical line of Kendall et al (1952). This illustration provides an introduction to the following section on the kinematics of the cervical spine, which specifically focuses on the gross sagittal movements of the cervical spine in flexion and extension.

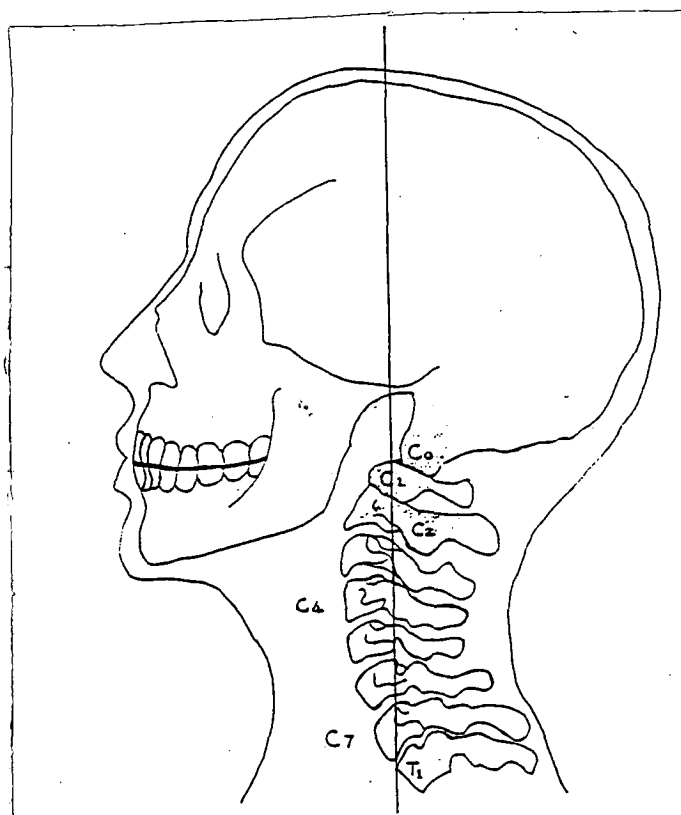


Figure 1.3. The cervical spine aligned with the vertical reference line of Kendall et al (1952).

1.3.1 Cervical Spine Kinematics

The study of the kinematics of the cervical spine describes the shape, and analyses the function of, the cervical lordosis (Panjabi 1974). Kinematics has been defined as 'that phase of mechanics concerned with the study of movement of rigid bodies, with no consideration of what has caused the motion' (White and Panjabi 1990 p. 90). The cervical spine is a chain of motion involving seven segments. A segment is defined as the basic vertebral unit, which consists of two bony parts (the vertebrae) and their flexible connections (Dvorak et al 1988, Panjabi et al 1986, White and Panjabi 1990). Differing amounts and directions of intervertebral flexion and extension movement have been observed at each segmental level in the cervical spine (Brunnstrom 1972). Debate about the positioning of intersegmental centres of flexion/ extension movement has occurred since the early 1900's, and there is conflicting evidence as to whether these centres of movement are sited in the vertebral body or the intervertebral disc (Bakke 1931, Fick 1904-13, Lysell 1969). Furthermore, individual differences have been observed in the location of centres of intersegmental flexion/ extension movement. These differences are considered to be dependent on the shape and design of the zygapophyseal joints, the uncinat processes and the discs within the individual (Friedenberg and Muller 1963, Huelke and Nusholz 1986, Panjabi et al 1986, Penning 1968, van Mameren et al 1990).

Integral to the flexion /extension movement in the sagittal plane is a translatory movement component⁵, which has been described as 'a movement of a body during which all parts of the body move in the same direction and with equal velocity' (Brunnstrom 1972 p. 8).

⁵. Translatory movement is more fully discussed in a later section of this chapter.

1.3.1.1 Cervical Units

Significant differences in design of cervical vertebrae and surrounding structures have been observed at segmental levels, and it has become traditional to divide the seven cervical segments into three distinct units (Jones 1960, Lysell 1969, Penning 1978, Torg et al 1977, Werne 1957).

These units are the upper cervical spine (C_{0-2}) (the occiput is referred to in this instance as C_0), the middle cervical spine (C_{3-5}) and the lower cervical spine ($C_6 - T_1$).

1.3.1.2 The upper cervical spine

The upper cervical spine is considered to comprise the most complex biomechanics of the spine (Dvorak et al 1988, Panjabi et al 1986, van Mameren 1988). Discs are absent from the two joints in this region and the atlas has been described as an interposed bearing between the occiput and C_2 (Penning 1978). Multi-directional movement is possible at each segment because of the individualised and specialised segmental arrangements of muscle fibres. Movement at this segment essentially occurs between the occiput and C_2 and is regulated by the atlas (Clark et al 1986, Dvorak et al 1987, Dvorak et al 1988, Werne 1957, White and Panjabi 1990). Gross flexion and extension in the upper cervical spine is limited by the osseous anatomy of the C_{0-1-2} vertebrae and the behaviour of the tectorial ligament. Wide variation has been observed in individual intersegmental flexion and extension movements (Penning 1978), and reports of mean intersegmental flexion/ extension movement at both the segment of C_{0-1} and C_{1-2} vary from 12 to 20 degrees (Dvorak et al 1988, Panjabi et al 1986, Penning 1978, van Mameren 1988, van Mameren et al 1990). Translatory movements in flexion/ extension are small because of the snug fit of the atlas around the dens of C_2 (Worth 1988).

1.3.1.3 The middle and lower cervical spine

The middle and lower cervical spine are integrally related due to the interwoven muscle fibres radiating in all directions from below the spinous process of C₂. Each muscle activates several segments, and gross cervical flexion and extension movement largely occurs in these units of the cervical spine. Varying amounts of flexion and extension are considered to occur at each middle and lower cervical spine segment, with mean values ranging from 10 to 23 degrees (Dvorak et al 1988, Panjabi et al 1986, White and Panjabi 1990). The largest range of intersegmental flexion/ extension movement is considered to occur at the segment of C₅ on C₆ (Dvorak et al 1988, Lysell 1969, White and Panjabi 1990). Intersegmental flexion/ extension movements in the middle and lower cervical spine have been shown to involve complex coupling of translatory and rotation movements (Lysell 1969). During flexion and extension, each cervical segment traces an arc, the flattest being at C₂ in the upper cervical segment, and the highest being at C₆. These arcs are illustrated in Figure 1.4. The different arcs reflect the different types of intersegmental flexion/ extension movement: from a gliding motion at C₂₋₃ to a tilting motion at C₆₋₇. While the C₆₋₇ segment is considered to be more mechanically stable than any other in the cervical spine because of its design, the C₅₋₆ segment is the least stable because of its anatomical position at the apex of the cervical lordosis (Panjabi 1974) (Refer to Figure 1.3).

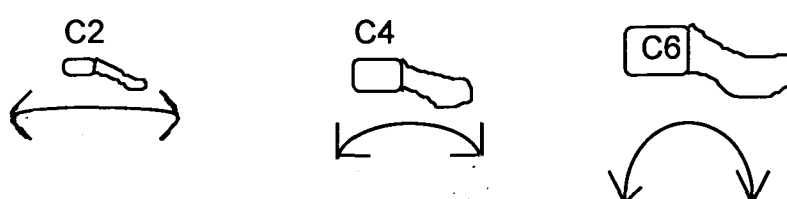


Figure 1.4. The arcs of movement traced during flexion/ extension movement

1.3.1.4 Translatory movement

It has been stated that translatory movement provides a mechanical advantage to individual cervical segments during gross flexion/ extension movement (White and Panjabi 1990). Increases in intersegmental translatory movement are considered to indicate 'abnormal' joint behaviour (Hohl and Baker 1964), and often are used radiographically to identify damage to the soft tissues components of a cervical segment (Weir 1975). Worth (1988) observed radiographically that individuals who had sustained a 'whiplash' injury had significantly larger amounts of intersegmental translatory movements occurring in the upper cervical spine than uninjured individuals.

Paradoxical translatory motion is typically found when one pattern of movement occurs in one spinal segment while the overall pattern of movement of the other segments is in the opposite direction. Paradoxical translatory motion typically occurs at the apex of a lordosis and thus, in the cervical spine, implicates the C₅₋₆ segment. Figure 1.5, based on an example provided by White and Panjabi (1990) (p. 89), illustrates the paradoxical movement of the middle aspect of the cervical spine which is implicated in flexion of the head. The upper cervical segments flex while the C₅₋₆ segments extend.

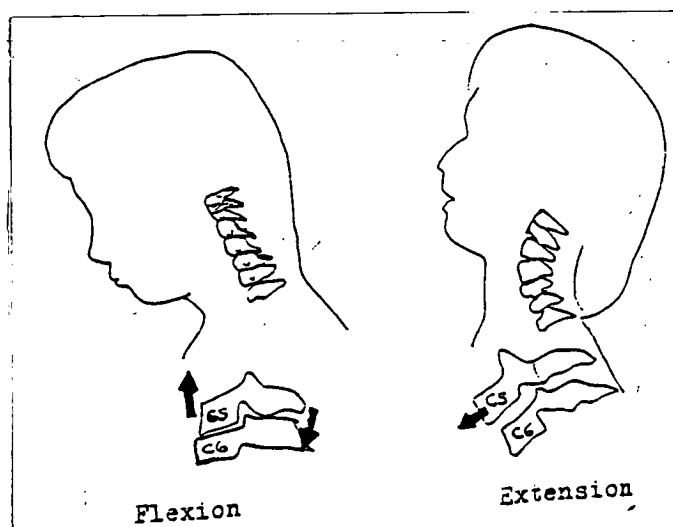


Figure 1.5. An illustration of the paradoxical translatory movement which occurs at C₅₋₆

White and Panjabi (1990) suggest that the usual amount of translation at the C₅₋₆ segment is in the order of 3 - 4 mm (p. 89). Frequent instability observed at this segment is explained by exaggerated translatory movement (Panjabi et al 1986), which is considered to result from factors such as habitual poor head posture (Mandal 1981, Moroney et al 1988, Panjabi et al 1986) and disease processes in cervical structures (Braaf and Rosner 1962, McNab 1971, 1973, Schonstrom et al 1993). Exaggerated translatory movement has also been associated with reduced neck muscle synergy, degraded joint capsule performance, 'abnormal' ligament tension, and degradation of expected intersegmental flexion/ extension movement (Fielding et al 1976, Hutchins 1966, Macdonald 1980, Mannheimer and Rosenthal 1991, Pearsall and Reid 1992, Penning 1988, Rocabado 1983, Wyke 1979).

It has been proposed that resting head posture perceived to differ from the 'norm' may be explained by individual differences in intersegmental centres of motion of flexion/ extension (Friedenberg and Muller 1963, Huelke and Nusholz 1986, van Mameren et al 1990). Exaggerated translatory movement at C₅₋₆ is also considered to reflect individual differences in intersegmental centres of motion (Panjabi 1974). This suggests that some individuals are more prone to developing poor posture than others because of the relative arrangement of the segments of their cervical spine.

It has been observed that the cervical spine can compensate for 'abnormal' movement at one spinal segment by altering the amount and angle of movement in adjacent segments (Fielding 1964, Jones 1960, Penning 1978). Such compensation comes at a cost however, as it places the adjacent cervical structures under increased biomechanical load and therefore at risk of subsequent degenerative changes (Worth 1988).

1.3.2 Habitual resting head posture

It has been stated that habitual individual resting posture of the head is determined by a dynamic combination of factors including body build (including individual intersegmental centres of cervical flexion/ extension), muscle performance, age related changes, mental state, proprioceptive capacity, occupation and cultural factors (Biernand and de Jong 1969, Darnell 1983, Fulton 1989, Hagberg and Wegman 1987, Hutchins 1966, Scranton et al 1978, Stainsbury and Gibson 1954, Thurnwald 1991, Troup 1988, Twomey and Taylor 1984). However, little is known regarding the specific nature of the causal mechanisms that lead to the assumption by an individual of a particular habitual resting head posture.

A wide variation in sagittal cervical spine posture has been demonstrated in never-injured subjects both radiographically (Fineman et al 1963, Gore et al 1986, Juhl et al 1962, Penning 1978) and clinically (Ayub et al 1984, Braun and Amundsen 1989, Cailliet 1989, Trott 1988). This underlines the reported variability in individual equilibrium responses when positioning the head relative to gravity (de Vries 1966, Dunsker et al 1978, Kendall et al 1952, Penning 1978, Turner 1956). Kendall et al (1952) claimed never to have examined any individual with posture perfectly aligned with the vertical reference line. While this may have reflected the nature of their reference population and their subject selection, it may also indicate that perfect posture, as classically defined in the literature and described in Figures 1.2 and 1.3, is unobtainable in real life.

A standard method of obtaining habitual resting head posture for the purpose of assessment has been described by Solow and Tallgren (1971). This method has been employed in studies by Siersback-Neilsen and Solow (1982), Goldstein et al (1984), Dalton (1989) and Watson and Trott (1991, 1993). The subject's head is first aligned with the gravitational axis. Natural Head Posture is then achieved when the subject's head comes to rest in the most comfortably balanced posture after three flexion and extension movements of decreasing amplitude.

Poor resting head posture, that which is considered to deviate markedly from a vertical reference line, has been widely proposed as a cause of headache (Ayub et al 1984, Basmajian 1979, Janda 1988, Jull 1986, Trott 1988). This proposal is based on the assumption that poor head posture stresses cervical structures which results in pain (Cailliet 1989, Dalton 1989, Darling et al 1984, Deng and Goldsmith 1987, Janda 1988, Richardson 1989, Saunders 1982). However, few studies have been conducted to clarify the concept of poor posture or to investigate the association between poor posture, structural stresses, strains and pain.

Perceived poor head postures are frequently described as 'Forward Head Posture'. However, depending on the author of the study, this description refers to different resting head positions. For example, Ayub et al (1984) and Sahrmann (1987) are relatively non-specific in their description of 'Forward Head Posture'. Ayub et al (1984) describe 'Forward Head Posture' as any posture where the 'head rests anterior to anatomical points of reference as described by Kendall et al' (p. 180).

More specifically, the term 'Forward Head Posture' has been employed to describe two different resting head postures. One of these postures describes a resting head held well in front of the line of gravity with the eyes level or angled downwards (Braun 1991, Cailliet 1989, Darnell 1983, Kendall et al 1952, Passero et al 1985, Raine and Twomey 1994, Stainsbury and Gibson 1954). In this position the trunk is slumped forward to support the head and level the eyes. This posture, described by Trott (1988) (p. 237), involves the cervical spine in a flattened lordosis (White and Panjabi 1990). It is illustrated by the first subject in Figure 1.6. The second resting head posture commonly described by the term 'Forward Head Posture' is that in which the chin leads, and the head is angled slightly upwards, tilted caudally within, or slightly anterior to, the line of gravity (Hanten et al 1991). This is illustrated by the second subject in Figure 1.6. Saunders (1982) describes this posture as 'a sagging forward of the head and neck with the face tipped upward' (p. 20-21). This posture implicates C₅ in an increased paradoxical translatory movement on C₆ because of the increased cervical lordosis (White and Panjabi 1990). Such an increase is required to counterbalance the weight of the head within, or close to, the vertical reference line (deVries 1966, Dalton 1989, Jull 1988, Macdonald 1980, Trott 1988).



Figure 1.6. Two specific head postures that have been described in the literature as 'Forward Head Posture'.

1.3.3 The measurement of cervical resting posture

1.3.3.1 In research settings

In research settings, several sophisticated methods have been employed to quantify and describe cervical resting posture. The range of intervertebral joint movement has been measured by X-ray techniques (Fielding 1957, Kottke and Lester 1958, Smidt et al 1984, Van Mameren et al 1990) and by computer-assisted anatomical positioning (Gervais and Marino 1983). An early method of measuring spinal angles from photographs (Loebl 1967) was revised and recently described by Braun and Amundson (1989), and was employed by Dalton (1989), Raine and Twomey (1994), Refshauge et al (1994) and Watson and Trott (1991) in recent Australian studies. While several angles describing resting posture can be measured using this approach, the most consistently reported angle is the craniovertebral angle. This is the resting angle of the head with respect to the lower cervical spine. This angle is illustrated in Figure 1.7, and is identified at the bisection of a line drawn between the spine of C₇ and the tragus of the ear; and a line drawn horizontally through the C₇ spine.

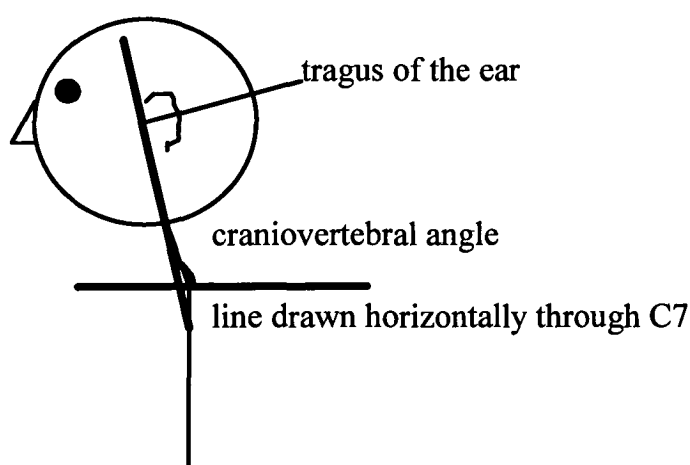


Figure 1.7. The craniovertebral angle as measured from photographs

1.3.3.2 In clinical settings

In clinical settings, time and expense limit the use of these methods of quantifying posture. There is however, no alternative standard, reliable method that can be applied in a clinical setting. Several recently reported methods of measuring cervical resting posture in a clinical setting are variations on the method of Kendall et al (1952), where the position of the head is measured and/ or described with respect to a vertical reference line (Ayub et al 1984, Bryan et al 1989, Darnell 1983, Passero et al 1985, Rheault et al 1989). However attractive from the point of view of time, cost and space efficiency, the subjectivity of this approach limits its usefulness both for taking repeated individual measures, and for describing the population range of cervical resting postures (Braun and Amundson 1989).

In an attempt to describe the dynamic nature of resting head posture, an alternative clinical approach has been suggested by Hanten et al (1991), who contend that 'stating that someone has Forward Head Posture based solely on resting head posture provides no information about the mobility in the excursion range, which may be more valuable' (p. 880). These researchers described the 'Total Head Excursion⁶' concept, measuring the maximum horizontal forward movement of the head from a fixed vertical point. They contend that the usual resting posture of the head lies within the 'Total Head Excursion' range, and that this provides a useful clinical indication of the overall health and performance of the cervical spine. The 'Total Head Excursion' concept is illustrated in Figure 1.8.

⁶. Excursion is defined by The Shorter Oxford Dictionary (1973) in the physical sense as 'deviation from a definite path or course'. This word is defined in common usage as 'a journey from any place with the intention of returning to it' (p. 699).

corrected starting position

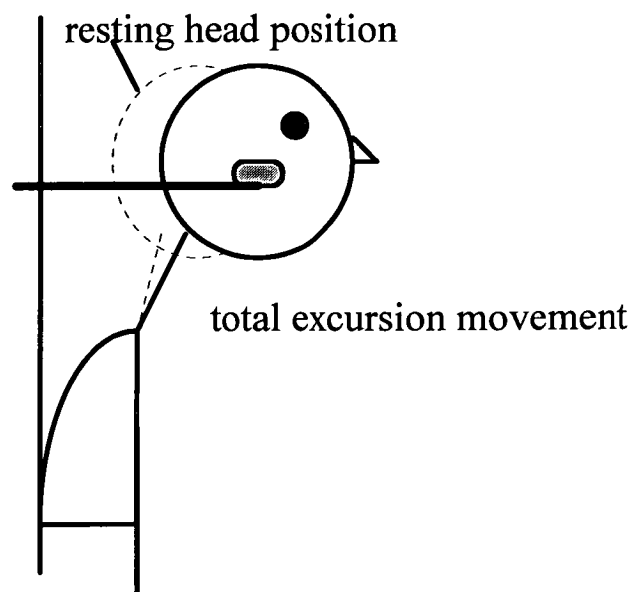
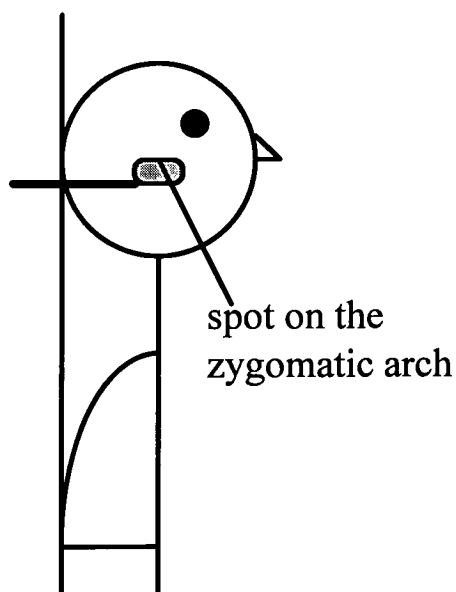


Figure 1.8. 'Total Head Excursion' concept

1.3.4 Summary

Poor cervical resting posture has traditionally been accepted as a causal agent of headache. No association has been demonstrated between one specific cervical resting posture and headache. Poor cervical resting posture is commonly described when the position of the resting head varies markedly from a vertical reference line. It is considered that poor cervical resting posture stresses cervical structures by increasing the antigravity load on them. Individual differences in the centre of intersegmental movement are considered to influence an individual's resting head posture. There is no standard method of describing or objectively measuring habitual cervical resting posture in a clinical setting.

Key Points

- There is no standard method of diagnosing and measuring headache specifically associated with cervical factors.
- None of the methods that have been previously employed to diagnose headache specifically associated with cervical factors are appropriate to a population-based study.
- An association between poor resting head posture and headache has traditionally been accepted, although this association has been subjected to few rigorous investigations.
- There is no evidence that one cervical resting posture is more strongly associated with headache than another.
- There is no standard method of describing or objectively measuring habitual cervical resting posture in a clinical setting.

Chapter Two

On conducting the study

This chapter reports on the development of measures of headache and cervical resting posture. This chapter also addresses issues of study design and investigates the role of other causes of headache, in the association between cervical resting posture and headache.

Evidence to support a causal relationship between cervical resting posture and headache is presented in Section 2.1. Section 2.2 addresses issues of study design and subject selection. Section 2.3 presents the methods that were developed to diagnose and measure headache in this study. The measure of cervical resting posture that was developed for this study, is described in Section 2.4. Section 2.5 identifies and discusses other causes of headache specifically associated with cervical factors, with respect to their role in the association between cervical resting posture and headache.

2.1 The association between headache and cervical resting posture

This study primarily tests the hypothesis that *cervical resting posture is associated with headache*. This section investigates the feasibility of such an association, using as a guide, standards for causality proposed by Hill (1965) and Susser (1991).

2.1.1 Consistency - the persistence of an association upon repeated testing

Clinical observations have consistently reported an association between posture and headache. These reports have largely been published as case studies in physiotherapy, dentistry, craniofacial surgery, occupational medicine, osteopathy, chiropractics and general medical practice (Abrahams 1977, Bibby and Preston 1981, Centonze et al 1992, Dunsker et al 1978, Edeling 1982, 1986, Janda 1980, 1988, Jull 1986, Kendall et al 1952, Lewit 1971, McKenzie 1990, Rocobardo 1983, Wägenhausen 1971, Weiss 1993). All studies reported a decrease in headache, neck and/ or face pain following adjustment of resting posture of the head to approximate a vertical reference line.

Anatomical studies have repeatedly implicated cervical structures with headache. Specific nerve pathways associated with headache were identified by using analgaesic blocks (Bogduk et al 1981-1988, Kerr 1961, Kerr and Olafsen 1961, Kimmel 1961). Recent cadaver studies described causes of trauma to cervical nerves as fractures in bony endplates, fissured discs, bruising and/ or muscle spasm, ligament disruption and cervical joint instability (Gurumoorthy 1991, Schonstrom et al 1993).

2.1.2 Plausibility and Coherence

This standard describes the extent to which the hypothesised association is compatible with pre-existing theory and knowledge. An association between poor posture and headache is both plausible and consistent with current knowledge (Abrahams 1977, Centonze et al 1993, Bogduk et al 1985, Bogduk and Marsland 1986, Janda 1980, 1988, Kendall et al 1952, Turner 1956, Weiss 1993). Poor cervical resting posture is considered to biomechanically disadvantage cervical structures, which are innervated by, or exist in close anatomical proximity to, the nerve roots that are implicated in the pain pathways associated with headache (Bogduk 1981, Kerr 1961, Kimmel 1961). Posture-induced dysfunction of cervical structures is thus a plausible cause of irritation of cervical nerve tissue, from which headache can result.

2.1.3 Analogy - like effects and causes

An analogy between human posture and structural engineering has been drawn (Basmajian 1979, Panjabi 1974, Panjabi et al 1986, Videman 1987), in which the poorer the alignment of moving parts, the greater the stresses on the coupling between the parts and the more likely the event of failure (Basmajian 1979). Good resting posture has been described when the body segments are aligned with a vertical reference line (Kendall et al 1952, Sahrmann 1987, 1988, Salminen 1984, Turner 1956, Wägenhausen 1971). Such positioning minimises energy expenditure and biomechanical stresses. Poor posture is thought to increase biomechanical stresses and energy expenditure (Basmajian 1979, Janda 1988). Poor performance of one spinal structure is compensated for, by overactivity of a related structure (Worth 1988).

2.1.4 Temporality, time order, direction of association

This standard describes the question: 'Which is the cart, which is the horse?' (Hill 1965). There is little evidence to support the temporality of association between posture and headache, despite assumptions by health care workers that cervical posture precedes headache (Centonze et al 1993, Janda 1988, Jull 1986, Trott 1988, Weiss 1993). Theories abound regarding the mechanisms by which posture is associated with headache, but there is no evidence from a prospective study that poor posture precedes events of headache.

2.1.5 Strength of association and the biological gradient

These standards evaluate the size and nature of the estimated risk. There is no published evidence of the strength or shape of an association between posture and headache.

2.1.6 Specificity - the precision with which posture predicts headache

There is no evidence that posture is uniquely associated with headache. It is believed that headache results from a number of different causal pathways (Dalesio 1987, Lance 1978, Waters 1987).

2.1.7 Summary

This section presented evidence to support the hypothesis that cervical resting posture is associated with headache. An association between resting posture and headache has been consistently reported in clinical testing, it is compatible with pre-existing theory and knowledge, and analogies can be drawn with coupling mechanisms described in structural engineering. There was also no evidence that headache had a more proximate cause on a causal path involving cervical resting posture.

2.2 The study design

Rothman (1986) describes the importance of observation in situations where the cause and effect occur in the population without deliberate manipulation of the environment. Such is the case with headache (Disease) and poor posture (Exposure). An observational study was appropriate to the study question. It would enable an estimation of the prevalence of headache, by expressing the number of subjects with headache as a proportion of the total sample. Time and cost dictated that the observational study be of a cross-sectional design, involving simultaneous collection of information on Disease and Exposure. A disadvantage of such a design was that it curtailed investigation into directionality of association between Disease (headache) and Exposure (resting posture) (Miettinen 1985, Susser 1991).

2.2.1 Preliminary studies

This study developed new measures of cervical resting posture, headache and cervical short flexor endurance because of the lack of standard, reliable measures of these factors in a clinical setting. Preliminary studies were therefore required to determine the robustness of these new measures and the reproducibility of their measurements¹.

¹. The new measures are described in this chapter and Chapter Three.

2.2.2 Subject selection

One method of assembling a representative sample of the population is to select individuals at random from a comprehensive population record such as the municipal electoral roll. Municipal rolls in Tasmania are reported to comprise approximately 85 per cent of individuals who live in the municipality and who are aged eighteen years and over (personal communication with the Tasmanian State Electoral Office 1992). Access to the municipal electoral roll is permitted in Tasmania to an eligible voter.

2.2.3 Exclusion criteria

Relevant exclusion criteria need to be applied to those selected individuals (potential subjects) to ensure that they have equal likelihood of Exposure and Disease (Fletcher et al 1988, Kelsey 1982, Kelsey et al 1986). Subjects who had never sustained an injury to the cervical spine were required so that the prevalence in never-injured individuals, of headache specifically associated with the cervical spine, could be established. The literature review indicated that exclusion criteria additional to the presence of cervical spine injury were also required to ensure equal likelihood of Exposure and Disease.

2.2.3.1 Degenerative conditions of the cervical spine

Subjects suffering from known degenerative conditions of the cervical spine would be excluded from the study on the grounds that such conditions are recognised causes of headache (Bland et al 1963, Bland 1967, Cabot and Becker 1978, Fournier and Rathelot 1960, Robinson 1966, Sharp and Purser 1961, Stevens et al 1971). Moreover, altered cervical posture has been associated with degenerative conditions of the cervical spine, where structural and/or metabolic changes have affected the usual performance of cervical structures (Foreman 1988, Friedenberga and Muller 1963, Hohl 1990, Holt and Yates 1966, Sahrman 1987, Weir 1975).

2.2.3.2 Pregnancy and breast feeding

Women who were pregnant or breast feeding would be excluded from this study in an effort to control for the potentially confounding effect of altered hormonal levels. These are believed to influence headache frequency (Silberstein 1992) and alter habitual posture (Cailliet 1989, Sahrmann 1987).

2.2.3.3 Classic migraine headache

Individuals taking medication for classic migraine headache would be excluded. Classic migraine headache is characterised by obvious neurological symptoms, vomiting and focal pain (Oleson 1988). These symptoms have been described as occupying the extreme right hand aspect of the continuum of headache symptoms (Marcus 1992, Sheftell 1992). Classic migraine headaches are considered to be of a distinctly different nature from headache whose symptoms occur at the left hand and central aspects of the headache continuum, which include tension-type, common migraine and headache associated with cervical factors (Jull 1986, Oleson 1988, 1991, Rapoport 1992, Silberstein 1992). After excluding known classic migraine sufferers, those individuals who remained in the study sample arguably experienced:

- primary benign headaches (symptoms located at the left hand and central aspects of the headache symptom continuum (Marcus 1992)),
- secondary headaches (i.e. those associated with space occupying lesions or substance abuse), or
- no headaches at all.

Subjects suffering headaches secondary to space occupying lesions, were unlikely to be found in large numbers, undiagnosed, in the population.

Subjects with headache secondary to substance abuse would be expected to readily identify the relevant causal agency.

2.2.3.4 Non-Steroidal Anti-inflammatory Drugs or Analgaesics

Individuals who regularly ingested non-steroidal anti-inflammatory drugs (NSAIDs) or analgaesics for any condition would be excluded from the study on the grounds that such medication influences headache intensity and frequency. However, NSAIDs can be taken as a regular headache management method, as well as for symptomatic congenital and/ or degenerative musculoskeletal conditions, and exclusion for this factor may influence the headache prevalence estimates in the study.

2.3 Headache associated specifically with cervical factors

2.3.1 Diagnosis

This study focused attention on the specific involvement of the cervical spine in headache events. In the studies dealing with headache associated with cervical factors, there was no standard method of identifying the involvement of the cervical spine, and there was no one diagnostic method that satisfied both clinicians and researchers (Bogduk and Marsland 1986, 1988, Bovim and Sand 1992, Edmeads 1988, Jull 1981, 1983, Pfaffenrath et al 1987, Sjaastad et al 1983).

Of the available diagnostic methods, three of the ten criteria for cervical origin headache, reported by Jull (1981) and described in Chapter One, lent themselves to adaptation as a diagnostic tool for the purpose of this study. Jull's Criteria Two, Six and Seven clearly described the involvement of the cervical spine in headache. All ten criteria had been collated by Jull from descriptions, provided by patients whose headaches she had treated. These patients' headache symptoms were accompanied by 'abnormal' cervical findings that had been detected by Jull's manual therapy tests.

For ease of reference, the criteria that specifically described the involvement of the cervical spine in headache are listed again in this section.

- 'Criterion 2: Occipital or neck pain is a frequent accompaniment (*of headache*).
- Criterion 5: Patients commonly wake with headache.
- Criterion 6: Headache is usually associated with sustained neck postures, tension or neck pain and movement' (Jull 1981, p.42).

Symptoms of headache on waking, and headache following sustained neck postures, have been mentioned by others as reflecting the specific influence of cervical structures on headache (Centonze et al 1992, Hasvold and Johnsen 1993, Jull 1981, Pfaffenrath et al 1987, Sjaastad et al 1983, Sjaastad 1987, Weiss 1993). While occipital or neck pain accompanying headache was believed to be non specific in identifying a particular headache aetiology (Bogduk 1987, Oleson 1988, Silberstein 1992), Criterion 2 focused attention on the cervical spine without detracting from the importance of the other two criteria. These three criteria, used together, offered a persuasive and clinically-based diagnostic tool for headache associated with the cervical spine, in a study where not all Diseased (headache) subjects were expected to have symptoms at the time of measurement. As the diagnostic tool, the criteria also were interpreted colloquially for ease of administration:

- You have pain at the back of the skull and/or in the neck when you have this headache (interpretation of Criterion 2).
- You often wake up with this type of headache (interpretation of Criterion 5).
- This type of headache is usually associated with holding your head in the one position for a long time, constant neck movement and/ or with tension (interpretation of Criterion 6).

2.3.2 Measuring headache (Disease status)

Collecting headache information presented a logistical problem for this study from two aspects: the type and method of data collection. Headache has been described in terms of intensity and frequency (Melzack 1975, Merskey 1984). Previous population-based studies of tension-type and migraine headache have generally reported on headache frequency, as this is more readily measured than intensity (Kaganov et al 1981, Pryse-Phillips et al 1993, Waters and O'Connor 1970, Waters 1974b). These studies informed the decision that this study would also primarily collect information on headache frequency.

A cross-sectional study measures Disease and Exposure status at the same point in time. Cervical resting posture is always present and measurements of it can be made at any time. On the other hand, headache specifically associated with cervical factors would be variably represented. There was no information to direct this study on the frequency of headache presentation, the stability of its characteristics, or the consistency of its occurrence.

Two options for collecting headache frequency data were considered. Information on headache frequency could be collected retrospectively by estimating the frequency of recent events of headache, or prospectively, by counting headache events as they occur over a given time period. To add to knowledge on headache associated with cervical factors, it was decided to collect data on headache frequency both retrospectively and prospectively.

2.3.2.1 Retrospective measurement of headache frequency

There was no standard method for retrospectively reporting headache frequency, despite the fact that individuals seeking treatment for headache usually complain of a recent history of unresolved symptoms (Edeling 1982, 1988, Jull 1981, Trott 1988). A time-based scale was thus developed to estimate the frequency of headache in the month prior to measurement. Time is a valid and clinically appropriate measure of frequency (Cole et al 1994, Holland 1983, Rothstein 1985, Solomon and Lipton 1993, Streiner and Norman 1989). The scale spanned a month, this being the minimum time required to definitively diagnose headache type (Russell et al 1992, Solomon and Lipton 1993). Sensitivity yet succinctness were required of the scale, so that it distinguished frequent from episodic headaches, but did not confuse subjects with similar choices (Streiner and Norman 1989). Construct validity of the scale could not be investigated within the study design. To do this required a comparison with a less variable measure of headache within the same time period (Armstrong et al 1992, Carmines and Zeller 1979).

2.3.2.2 Method of administering the retrospective scale

There is a risk of measurement bias if investigators are aware of subjects' Disease status at the time of data collection (Sackett 1979), and an independent measurer is therefore often employed to measure Disease. When costs preclude the use of an independent measurer, as in this study, an alternative method of collecting information on Disease status is a written questionnaire, completed by the subject without assistance from the investigator (McDowell and Newell 1987, Sackett 1979, Salminen 1984). A written questionnaire is time and cost efficient (Kidder and Judd 1986) and it has been used in population-based studies which investigated other headache types (Kaganov et al 1981, Pryse-Phillips et al 1993, Waters and O'Connor 1970, Waters 1974b).

2.3.2.3 Collecting prospective information on headache

A prospective diary that collects daily information on headache is a precise diagnostic tool (Andrasik and Holroyd 1980, Merskey 1986, Solomon and Lipton 1993). A diary is also commonly used by physiotherapists to assess the outcome of treatment for a range of conditions (Cole et al 1994). A daily diary, used in conjunction with the diagnostic tool for headache, was thus chosen for this study to collect prospective information on headache.

2.3.3 Headache frequency categories

Studies on headache associated specifically with cervical factors have previously been undertaken on self-selected subjects with frequent headache. Frequent headaches have been described as occurring twice or more per month (Edeling 1988, Jull 1986, Watson and Trott 1991, 1993). It has been reported that tension-type and migraine headache both occur in the population in occasional and frequent forms (Bakal and Kaganov 1979, Kaganov et al 1981, Matthew et al 1982, Saper 1986). As headache associated with cervical factors has similar symptoms, it was hypothesised that *headache associated with cervical factors occurred in both occasional and frequent forms*. Occasional headache would be identified from the retrospective headache scale as headache occurring less frequently than twice per month. The separate nature of occasional headache from no headache, and from frequent headache, needed to be established prior to testing the association between headache and posture. Failure to do so would invite misclassification of Disease (Rothman 1986).

2.4 Cervical resting posture

2.4.1 Measurement of excursion

A new method of measuring cervical resting posture in a clinical setting was developed for the purpose of this study. It was based on the 'Total Head Excursion' concept (Hanten et al 1991). Hanten's method measured the horizontal excursion movement of one point on the skull relative to a vertical reference line, and measurements were reported by these researchers as reproducible.

Assumptions were made, when developing the concept of Hanten et al (1991) as the new measure of cervical resting posture, that:

- it was valid to combine horizontal and vertical measurements of excursion of the one anatomical point and interpret this as an angle of excursion;
- this angle of excursion approximated the degree of correction required to align the chosen anatomical point with the vertical reference line; and
- the angular excursion of anatomical points situated at the distal and proximal aspects of the cervical spine approximated the shape of the cervical lordosis.

The components of the measurement of cervical resting posture are depicted in Figure 2.1.

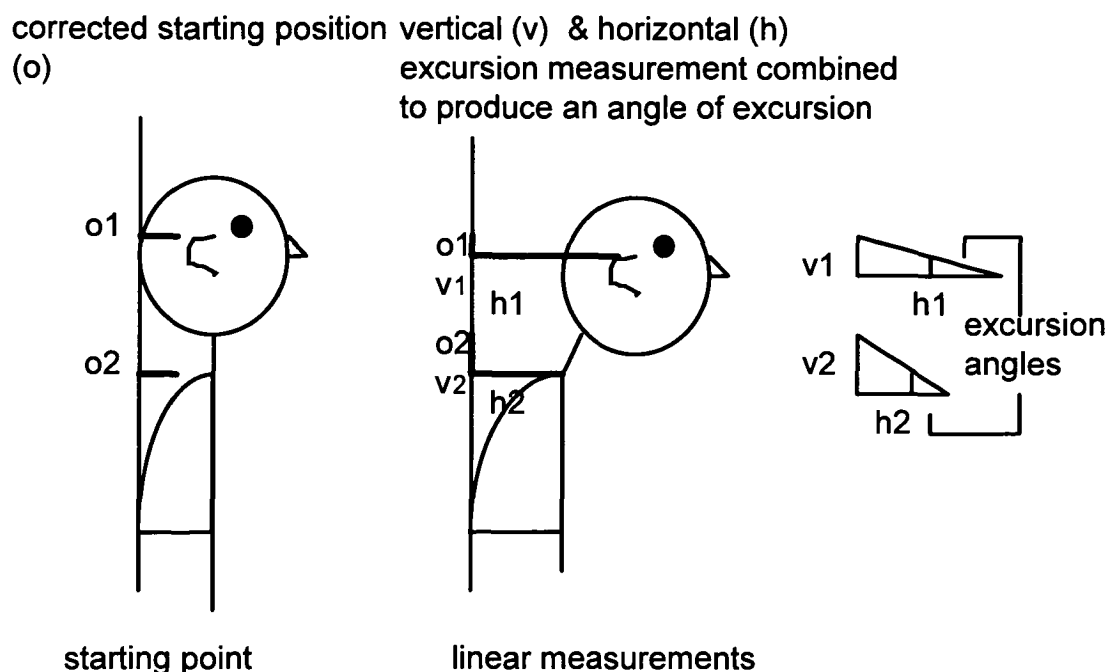


Figure 2.1. The component measurements of cervical resting posture. The horizontal excursion (described as h1 and h2) and the vertical excursion (described as v1 and v2) of each anatomical point are combined and expressed as angles of excursion.

2.4.2 Extreme excursion angles

Habitually poor cervical resting posture was the putative cause of headache in this study. However, two markedly different resting head postures have been described as poor³, and there are no reports that one particular resting posture is more strongly associated with pain than any other. Therefore identification of the cervical resting posture most strongly associated with headache was an essential element of this study.

³. Both these postures are called 'Forward Head Postures': the head held well in front of the vertical reference line, and the head caudally rotated within, or slightly anterior to, the vertical reference line. They were described in Chapter One.

Kendall et al (1952) and Penning (1978) describe the wide variability in habitual cervical resting postures of individuals without injury or degenerative disease. On this basis, this study hypothesised that *no subject in this study had resting posture perfectly aligned with the gravitational line*: that is, in assuming habitual resting posture, every individual's head excursed some distance from the vertical starting position. It was also hypothesised that *there was wide variability in the angular excursion of the upper and lower aspects of the cervical spine*.

This study described habitual cervical resting posture in a different manner from any previous study. Instead of using a vertical reference line as the marker of 'good posture', it was described by the head posture associated with the average excursion angles in the study sample. This marker of 'good posture' described the average response of never-injured individuals to the effect of gravity on head-on-neck posture and was appropriate to the usual visual inspection approach of a clinical setting.

This study also tested the hypothesis that *individuals with excursion angles occurring at either extreme of the population range had 'poor' habitual cervical resting posture*. Two methods were proposed to identify extreme excursion angles in the data.

1. If the excursion angle data approximated the Normal frequency distribution, the rule of deviation from the mean could be applied to it to identify extreme angles (Runyon and Haber 1972). Extreme angles were those that fell beyond the first, second or third standard deviations from the mean.

2. If the excursion angle data did not approximate the Normal distribution, subjects with extreme angles could be identified by one of two methods:
 - i. transforming the data to approximate the Normal distribution, and then treating it as described previously (in 1), or
 - ii. arbitrarily dividing the data into categories of relatively equal size and identifying the first and last categories as extreme (Cramer 1991, Rothman 1986). The use of categories of the exposure term reduces reliance on assumptions of normality, and analysis is not influenced by outlying points (Baron et al 1984). Estimates of odds ratios of disease in each category of the exposure term can be made without limiting the investigation to one pattern of association (Poole et al 1984). The use of five divisions (quintiles) in parametric data minimises the loss of definition of association that can occur when dividing continuous data into broad categories (Cramer 1991).

2.4.3 The exposure term for model testing

The angular excursion of the upper and lower aspects of the cervical spine needed to be expressed in a manner appropriate to the model used to test the hypothesis that *cervical resting posture is associated with headache*. Options were to combine the excursion angles and express them as one exposure term, or consider them as separate terms in the model.

A single exposure term would simplify model testing. It could be constructed if there was a high level of association between the two angles of excursion (Maher 1993), and if evidence could be provided of similar biomechanical activity occurring at each anatomical point during postural manoeuvres.

If a single exposure term could not be constructed under these terms, the excursion angles would require separate investigation with headache. The use of separate exposure terms would complicate model testing. The excursion of one anatomical point would need to be identified as the primary exposure, and alternative roles would need to be considered for the excursion of the other anatomical point. A description of investigations to determine the exposure term most appropriate to the data, is provided in Chapter Seven.

2.5 Other causes of headache

Cervical resting posture is but one of many possible causes of headache (Dalezio 1987, Lance 1978). Other causes of headache were identified and measured in this study in order to control for confounding, and to identify modifying influences on the association between cervical resting posture and headache.

2.5.1 A confounder

A variable acting as a confounder has an association with both Disease and Exposure, it is not a predictor of Exposure and it is not an intermediate cause of Disease (Rothman 1986). The true strength of a relationship is obscured by the action of a confounder (Greenland 1989, Rothman 1986) and therefore account needs to be taken of its effect. A change in the crude odds ratio of ten per cent or more provided evidence of a confounding effect (Greenland 1989, Rothman 1986).

2.5.2 Effect modification

Effect modification occurs when 'the magnitude of the chosen measure of association between a causal agent and disease differs according to the level of a third variable (or two or more variables)' Kelsey et al (1986) (p.16).

Many causes of headache have been reported in the literature, and no one cause is considered to be sufficient to induce headache. Complex biological mechanisms are considered to influence posture of the head on the neck (Sahrmann 1988, Solow and Tallgren 1971, Wägenhausen 1971), and thus the possibility exists of interactions between determinants of headache.

Effect modification occurs when the effect of a third variable on an hypothesised association is non-uniform, that is, when the effect varies across strata (Walter and Holford 1978). The methodology for evaluating interaction effects 'has been hotly debated' (Rothman 1986, p. 311) because of theoretical differences underpinning the concepts of statistical and biological effect modification. Effect modification requires an assumption of independence of distribution of the relevant factors (Koopman 1981).

Greenland (1989) considers that effect modification is identified by differences between stratum odds. The size and significance of this difference has not been well defined, largely because of the subtleties of biological interaction (Rothman 1986). Moreover, the power of tests for difference between strata is recognised as being low (Rothman 1986, Greenland 1989) because of influences of biases such as selection, misclassification and confounding.

The correct choice of the most appropriate statistical model with which to assess the modification effect is difficult where there are limited insights into the nature of the proposed associations. A significant difference between strata was identified by a common odds *p value* of the order of 0.15 or less. Greenland (1989) and Walter and Holford (1978) support the choice of a higher significance level in the situation where insights are limited, and where spurious effects may be produced by small numbers of subjects with combinations of relevant risk factors.

2.5.3 Antecedent and intermediate factors

An antecedent factor acts via the Exposure on the Disease (Rothman 1986), while an intermediate factor results from the Exposure, and is more proximate to Disease than the Exposure. Antecedent and intermediate factors to headache were closely considered in this thesis, in an attempt to develop insights into specific effects of posture on headache. The literature review described the common belief that resting head posture is dynamic, involving complex relationships between a wide range of factors (Basmajian 1979, Janda 1988, Kendall et al 1952, Salminen 1980, Turner 1956, Wägenhausen 1971). Antecedent and intermediate causes of headache, acting via, or as a result of, cervical resting posture are correlates of Exposure. They cannot therefore be treated as confounders and/ or modifiers of the association between posture and headache unless arguments can be presented for independence of action under certain circumstances. Inherent measurement error anticipated a stronger association between antecedent factors and excursion angles, than with headache. On the other hand, intermediate causes of headache will be associated with both posture and headache.

2.5.4 Causes of headache other than cervical resting posture

Causes of headache other than cervical resting posture were identified from the literature on headache and 'whiplash' injury, and were classified into five groups for ease of reference.

1. Anthropometric variables (length and circumference of neck, body mass, breast size for women) were defined as those 'belonging to the measurement of the human body with a view to determine its average dimensions' (The Shorter Oxford English Dictionary 1973, p. 79).
2. Functional variables (cervical muscle performance, cervical joint range of movement) were defined by Janda (1983) as 'those variables associated with the nature of movement' (p. 83).
3. Physical characteristics (age, gender, wearing dentures and glasses, physical activity, the effect of the menses for women) were defined as 'those which serve to indicate character.... a distinctive mark, a distinguishing peculiarity or quality (The Shorter Oxford English Dictionary 1973, p. 315).
4. Social factors (occupation, working hours) were defined as 'consisting of persons living in communities desirous of enjoying the companionship of others' (The Shorter Oxford English Dictionary 1973, p. 2041).
5. Emotional factors (anxiety, depression, vitality, health status, self control, wellbeing) were defined as 'a mental feeling, as distinguished from cognition or volition' (The Shorter Oxford English Dictionary 1973, p. 647).

There was little available information to describe the nature of association between headache and these proposed causes. Furthermore, there was a lack of information on the relationship between these proposed causes of headache, and cervical resting posture. For the purpose of this study, scenarios were described to more clearly define cervical resting posture, and the relationship between it and other proposed causes of headache.

1. Habitual cervical resting posture develops during childhood, adolescence and early adulthood. It is systematically influenced by anthropometric, functional, physical, emotional and social variables. In this scenario, these variables are correlates of developing posture, and via it, antecedent factors to headache.
2. Once its developmental phase has ceased (with adulthood), cervical resting posture is established and consistent (Raine and Twomey 1994). It is no longer systematically influenced by anthropometric, functional, physical, emotional and social variables. However, these variables continue to influence moment-by-moment adjustments that maintain the position of the head on the neck against the force of gravity. In this scenario, the anthropometric, functional, physical, emotional and social variables are correlates of established posture, and via it, antecedent factors to headache.
3. Where cervical resting posture is established, certain physical, emotional and social factors can be independent causes of headache under specific circumstances. In this scenario they may confound and/ or modify the association between established cervical resting posture and headache.

On the basis of these three scenarios, mechanisms were proposed to describe the relationship between headache and its other causes.

2.5.4.1 Cervical resting posture in the proposed study sample

The names of individuals under the age of eighteen are not recorded on Australian municipal electoral rolls. The use of the electoral roll as a source of subjects for this study assumed that subjects were adult, and had established cervical resting posture. Proposals Two and Three were therefore appropriate to subjects in this study. While the cross-sectional nature of the study allowed only a limited, 'point in time' snapshot of never-injured subjects, this was the first population-based study on headache associated with cervical factors, and estimates of the strength of association of headache and its causes would be reported to inform future studies.

2.5.4.2 The influence of anthropometric variables

Length of neck

Neck length was proposed as a correlate of cervical resting posture, and via posture, as an antecedent cause of headache. A long neck is believed to reduce the mechanical advantage of the cervical muscles because of the distance separating the origins and insertions (Janes and Hooshmand 1965). This affects the length /strength of muscle ratio (Janda 1988, Richardson 1989) and influences underlying support for head-on-neck posture. The long neck is more likely to be affected by the 'whipping' motion of a hyperflexion/ hyperextension injury than a short one (Janes and Hooshmand 1965). The performance of the upper cervical spine has been closely associated with the performance of the temporo-mandibular joint because of the interconnections between the bony structures and the soft tissues (Bench 1963, Bibby and Preston 1981, Funakoshi et al 1976, Prieskel 1965, Rocobardo 1983, Stoll 1966). On available biological theory, it was not anticipated that neck length was independently associated with headache.

Circumference of the neck

Circumference of the neck was proposed as a correlate of cervical resting posture, and via posture, as an antecedent cause of headache. The literature suggested that the larger the neck circumference, the more stable the neck, because of increased bulk (Janda 1988) and a wider centre of gravity (Janes and Hooshmand 1965). Stability of cervical resting posture was defined for the purpose of this study as non-extreme excursion angles at the upper and lower cervical spine. On available biological theory, it was not anticipated that circumference of the neck was associated independently with headache.

Body build

Body build was measured in this study as height and weight, and expressed as a Body Mass Index. This was proposed as a correlate of cervical resting posture, and via posture, as an antecedent cause of headache. Extremes of height (very tall and very short) have been reported as determinants of poor cervical resting posture (Turner 1956), as they involve habitual gross cervical flexion (for the tall individual), and habitual gross cervical extension for the short individual. Height and weight exert an influence on the length/ strength ratio of muscles in the cervical spine and the bulk of an individual's neck. It has been observed that a tall thin body has more variable habitual head on neck posture than a shorter, broader individual because of the narrower centre of gravity and reduced mechanical advantage of the head on neck movement (Cailliet 1989, Raine and Twomey 1994), lesser resistance to impact and increased biomechanical stresses (Sahrmann 1987, Salminen 1984). On available biological theory, it was not anticipated that body mass was an independent cause of headache.

Breast size

The nature of the association between breast size and headache was unclear. Women with large breasts have been observed to suffer more headaches than women with small breasts, and they have also been observed to have poorer cervical posture (Gonzalez et al 1993). Large breasts are reported to drag on the lower neck and shoulders, destabilising head on neck posture and disadvantaging usual performance of cervical structures. Large breasts place a consistent downward force on the anterior chest wall. Breast size in this instance is a correlate of posture, acting in an antecedent fashion to headache. The weight of the breasts is carried by the lower cervical and the upper thoracic spine (Cailliet 1989), and the way in which thoracic and lower cervical activity influences upper cervical posture has not been well described.

Where habitual adult cervical posture becomes established before breast size is fully developed, breast size may act independently of cervical resting posture, on headache. A particular instance of this is immediately after pregnancy. In this instance, breast size will confound and/ or modify an association between posture and headache in women.

2.5.4.2 The influence of functional variables

The nature of the association between functional variables and headache has not been well described. On current knowledge, this study proposes that functional variables are correlates of posture under all circumstances involving never-injured adults, acting in an antecedent or an intermediate fashion with headache. They are not independently associated with headache. Ways in which the functional variables are correlated with posture are proposed:

1. The functional variables are significant influences on developing and established posture, as they primarily maintain a level gaze and counteract the effect of gravity. They act in an antecedent fashion with headache, via posture.
2. When established cervical resting posture is 'poor', there is a systematic and cyclic relationship between it and the functional variables. Habitually 'poor' cervical resting posture degrades cervical muscle performance and cervical range of movement. The functional variables in this instance are intermediate causes of headache, as they are more proximate to headache than cervical resting posture.

Cervical Muscles

Clinical studies report that poor performance of the cervical flexors and extensors is associated with both posture and headache (Janda 1988, Jull 1988, Richardson 1989). Shortened and inadequate cervical extensor muscles have been observed in subjects with poor cervical posture and chronic headache (Trott 1988, Arena et al 1991), and poor cervical short flexor endurance has been observed in women with 'Forward Head Posture' and frequent headache (Watson and Trott 1991, 1993). This study examined the association of headache with the strength and endurance of major cervical muscle groups.

Endurance

Muscle endurance is the ability to persist in physical activity (DeVries 1966). Isometric muscular endurance has been described as 'the time a subject holds a maximum contraction.....the effects of energy depletion upon maximal contraction are observed over time' (Fulton 1989, p. 83). The cervical short flexor muscle group comprises rectus capitus anterior and lateralis, longus capitus and longus colli (Basmajian 1979, Davies 1972), which extend over the upper and middle cervical spine (Gurumoorthy 1991). These muscles provide stability and mobilise the skull on the vertebral column (Fulton 1989, Richardson 1989). The performance of this muscle group is usually measured as endurance capacity. Janda (1988) suggests that the full role of this muscle group will never completely be described because it is not readily accessible to investigation in live subjects. A measure of cervical short flexor muscle endurance needed to be developed for this study because no objective measure of it was available in a clinical setting.

Strength

Muscle strength has been defined by Caldwell et al (1974) and Kroemer (1970) as the maximum force that muscles can exert in a single voluntary effort. It is measured as the 'external effect of internal isometric muscle efforts, modified by the mechanical advantages of the body members involved' (Fulton 1989, p. 83). Long cervical flexors (sternocleidomastoid and scalene muscles) control head posture (Richardson 1989), because they stabilise the upper cervical spine (Basmajian 1979, Moore 1985). The long cervical extensors (the upper fibres of trapezius and components of erector spinae) maintain an erect head (Basmajian 1979, Kendall et al 1952, Sahrmann 1988).

The actions of the long extensors and flexors have been well documented because of ease of viewing and palpation, during passive and active movement (Basmajian 1980, Brunnstrom 1972, Moore 1985).

Synergy

In usual circumstances, muscles operate in synergistic relationships, that is, no muscle operates in isolation (White and Panjabi 1990). Synergy is defined by The Shorter Oxford Dictionary as 'combined or correlated action of a group of bodily organs' (p. 2224). Complex synergistic relationships have been observed in the muscles acting over one joint (Basmajian and Travill 1961), and differing reciprocal relationships between agonist/ antagonist muscles under normal and reflex circumstances have been noted (Bertoz and Metral 1970, Cohen 1970, Lestienne and Goubel 1969, Patton and Mortenson 1970, Richmond et al 1992). The moment-by-moment adjustments required to maintain adult head-on-neck posture against the effect of gravity involve complex relationships between the cervical muscles (Janda 1988, Richardson 1989). The relationship between cervical muscles during these adjustments has not been well described. Inter-relationships between other muscles have been reported in multivariate linear forms using measures of Electromyographic (EMG) activity (Allum et al 1993, 1994, Allum and Honegger 1993). Linear relationships have been reported in the performance of the abdominal muscles during active lumbar stabilisation (Jull et al 1993, Richardson et al 1990), co-contraction of the wrist flexors and extensors (De Serres and Milner 1991), muscle function in the spastic lower limb (Perry 1993) and muscle function in walking of subjects with injured and non-injured knees (Schiavi et al 1992). The measurements of muscle performance reported from this study will inform future investigations into muscle synergy in postural mechanisms.

Range of cervical movement

Cervical joint dysfunction has been associated with reduced range of neck movement (Bogduk and Marsland 1986, Penning 1978, White and Panjabi 1990). Of all the gross movements traced by the cervical spine, lateral flexion movement has been proposed as the best indicator of the overall health of the cervical spine because of the complexity of the intersegmental coupling (Dvorak et al 1988, Panjabi 1974). Cervical extension range of movement is a useful measure of gross cervical spine flexibility in the sagittal plane (Dvorak et al 1988, White and Panjabi 1990). A primary movement of lateral flexion involves secondary components of flexion/ extension and rotation at all spinal segments (Aprill et al 1990, Penning 1978, White and Panjabi 1990). The rotatory component is considered to be particularly important in determining the quality of lateral flexion movement (Bogduk and Marsland 1986). In the upper cervical spine, rotation occurs simultaneously with lateral flexion because of mechanics associated with the lateral shift of the bony masses of C_1 and C_2 . The ratio of rotation to lateral flexion at these levels has not been described in a standard fashion (White and Panjabi 1990). The upper cervical nerve roots implicated in headache juxtapose the upper cervical structures, and poor quality upper cervical intersegmental movement patterns during lateral flexion stress adjacent structures (Bogduk and Marsland 1986). Variable coupling ratios of rotation to lateral flexion have been described in the middle and lower cervical spine during primary lateral flexion movement. These range from 2:3 at C_2 to 1:7 at C_7 . (Dvorak et al 1988); the ratio is reported to be dependent on the anatomical position of the intervertebral joints (Panjabi 1974, White and Panjabi 1990).

2.5.4.3 The effect of physical variables

There is little information on the nature of association of physical variables with headache.

Age

Age has been described as a proxy measure of the cumulative effects of biological wear and tear on musculoskeletal and neural structures (Twomey and Taylor 1984). A relationship between age, decreasing range of joint motion and increasing frequency of neck pain has been widely reported (Brain et al 1952, Penning 1968, Selecki 1984, Westerling and Jonsson 1980, Wickstrom et al 1970). Age-related changes to the cervical spine joints have been specifically associated with headache (Trott 1988), and with altered resting head posture (Fulton 1989, Dalton 1989). Age is believed to act in an antecedent fashion with headache, via posture or other causal mechanisms, by influencing cervical muscle and cervical joint performance.

Physical activity

Regular physical activity is a method of maintaining normal spinal biomechanics, good body posture and self-esteem (Merskey 1984, Sikorski et al 1989, Strang 1985, Troup 1988, Westerling and Jonsson 1980). Physical activity can be measured in a number of ways. Resting pulse rate is a standard objective measure of cardiovascular fitness (Egger and Champion 1987). A sport score, the product of the frequency and type of sport (Lamb and Brodie 1991) express the amount energy expended during recreational pursuits (Buskirk et al 1971, Taylor et al 1978). Physical activity is believed to be correlated with cervical resting posture and the functional variables, acting in an antecedent fashion with headache.

Wearing dentures

Inefficient (less than normal) function of the temporo-mandibular joint (TMJ) function has been associated with similarly poor performance of the upper cervical structures (Ayub et al 1984, Rocobardo 1983, Thurnwald 1991), instigating postural inefficiencies which may result in headache (Weiberg and LaPointe 1987). Wearing dentures directly affects the mechanical advantage of the bite mechanism (Rocobardo 1983). The effect of wearing dentures is believed to be correlated with posture if dentures influence postural development. Dentures are independently associated with headache when they are first worn after posture has become established.

Wearing glasses

Deficient vision and poorly fitting glasses have been associated with headache (Wolfe and Cathey 1983) via posture changes and 'abnormal' cervical muscle activity (Lance 1982). The effect of glasses is believed to be correlated with posture if wearing glasses influences postural development. Glasses are independently associated with headache when they first are worn after posture becomes established.

Gender

Women are reported to suffer more headaches than men (Dalessio 1987, Lance 1982, Waters 1974b, 1987). Gender differences in headache mechanisms have not been well described. Gender differences in cervical resting posture have been observed (Dalton 1989, Fulton 1989), which may be due to differences in muscle performance and habitual cervical spine positioning. However, it was anticipated that the cervical spine in never-injured individuals should perform similarly well for men and women, and that gender would not influence the prevalence of headache associated with cervical factors. This study provided a unique opportunity to describe the gender effect on the prevalence of headache specifically associated with cervical factors, and on the association between posture and headache.

Menses

For women, headache has been associated with fluctuations in hormonal levels during the menstrual cycle (Keenan and Lindamer 1992, Silberstein 1992). It was proposed on this basis that the effect of menses was an independent cause of headache associated with cervical factors.

Oral contraceptives

No information was collected in this study from women on oral contraceptive use because a recent study indicated that it influenced neither the intensity nor the frequency of tension-type headache (Mraz et al 1993). Furthermore, it was considered that such questioning was unnecessarily intrusive, as it had little bearing on the study hypotheses.

2.5.4.4 The influence of social variables

Of all the proposed social variables, the nature of the association of social variables with headache was most readily described for occupation. In a similar fashion to the action of the physical variables, the mechanism of action of the social variables with headache was believed to be via the functional variables (cervical muscle performance and cervical range of movement).

Earning capacity and hours of work

The variables of earning capacity and hours of work have been associated with headache because of family and occupationally-related stress and workplace fatigue, and because of the influence of stress on the performance of cervical soft tissues (Hult 1954, Hagberg and Wegman 1987). These variables were believed to be correlates of posture, and via posture, antecedent causes of headache.

Occupation

Associations have been observed between occupational demands, neck and shoulder pain and headache (Hult 1954, Hagberg and Wegman 1987, Linton and Kamwendo 1989, Westerling and Jonsson 1980). Repetitive occupational postures have been associated with poor performance of cervical structures (Janda 1983) while heavy occupations have been reported as protective of headache. The pursuit of a heavy occupation can increase the strength and bulk of the shoulder / neck muscles (Hult 1954).

Occupation was considered to be a correlate of posture and an antecedent cause of headache, if it influenced postural development. However, occupation was an independent cause of headache if its effect was first felt after posture became established.

2.5.4.5 The influence of emotional variables

The mechanical nature of headache associated with cervical factors does not support a direct causal relationship with measures of emotion (Bogduk 1989). However, emotional influences have been associated with chronic headache (de Benedittis and Lorenzetti 1992, Ellard 1970, Hohl 1974, 1990, Merskey 1984, McNab 1973, Mitchell 1988), where the expectation of regular pain involves emotion aspects in the causal mechanism (Merskey 1984, Troup 1988). Emotional influences in this instance would be a correlate of Disease (Weinberg 1993).

2.5.5 Summary

There was little biological theory to direct hypotheses regarding the nature of associations between headache and its causes. On this basis, investigation of associations between headache and causes other than cervical resting posture, would be restricted in this study to:

- the one variable with a clearly independent association (the effect of the menses for women), and
- those variables whose association with headache was independent, under specific circumstances. These variables were breast size for women, and occupation, wearing glasses and wearing dentures for men and women, when they acted on established posture.

All the other causes of headache were believed to be correlates of either Exposure (posture) or Disease (headache). The functional variables, cervical muscle performance and cervical range of movement, were proposed as underpinning the association between headache and its physical and social causes.

Key Points

- There was evidence using standards for coherence, consistency, plausibility and analogy (Hill 1965, Susser 1991) to support the hypothesis that cervical resting posture was a cause of headache in never-injured individuals. Without information on more intermediate effects, cervical resting posture was proposed as the most proximate cause on a causal path for headache.
- An observational study would enable the prevalence of headache in randomly selected, never-injured individuals to be described. A cross-sectional design suited the cost and time constraints of this study.
- Specific exclusion criteria needed to be applied to potential subjects to ensure never-injured status, and an equal likelihood of Exposure and Disease in the study sample. These criteria included memorable trauma to the neck, known degenerative spinal conditions, taking medication for classic migraine headache, taking anti-inflammatory or analgaesic medication, and for women, breast feeding or pregnancy.
- A diagnostic tool for headache was developed from existing descriptions that focused on the cervical nature of headaches.
- In order to clearly describe headache associated with cervical variables, two methods were proposed to collect information on headache frequency. A time-based scale was required to retrospectively measure headache frequency. The scale needed to be sufficiently discriminatory to distinguish occasional headache from frequent headache and from none, and sufficiently succinct so not to confuse subjects with a multitude of choices. Information on headache frequency would also be collected prospectively using a diary. Headache information would be collected over two months, retrospectively over a month and prospectively for a month.

- A method of objectively measuring cervical resting posture in a clinical setting would be developed, based on the Hanten et al (1991) concept of 'Total Head Excursion'. This method would provide horizontal and vertical measurements of excursion of points on the upper and lower cervical spine. The linear measurements would be expressed as angles of excursion.
- The merits were considered of combining the two excursion angles, or treating them separately during model testing. The decision regarding the most appropriate exposure term depended on the strength of the association and the biological relationship between the excursion angles.
- Causes of headache, other than cervical resting posture, were identified and then broadly categorised by characteristics. The nature of associations with headache were proposed on available (limited) biological theory.
 - Variables that significantly influenced cervical resting posture during its development, or during the moment-by-moment adjustments necessary to maintain an erect head against the effect of gravity, were proposed as correlates of posture, and antecedent causes of headache, via cervical resting posture.
 - Under specific circumstances, where posture was already established, breast size for women, and occupation and wearing glasses and dentures for men and women, were proposed as confounders and/ or modifiers of the association between posture and headache. The effect of the menses for women was believed to be independently associated with headache.
- Gender effects in the prevalence of headache, and on the association between headache and posture, would be investigated.

Chapter Three

Method

This chapter describes the study method. Section 3.1 presents the main hypotheses. Section 3.2 describes the method of obtaining the study sample and Section 3.3 outlines the study protocol. Section 3.4 describes the diagnostic tool for headache and the scale developed to measure headache frequency. Section 3.5 describes the posture measuring device and details the protocol for measuring cervical excursion. Section 3.6 deals with the measurement of all other study factors. Section 3.7 reports on the methods used to analyse the data.

Approval for this study was obtained from the Human Research and Ethics Committee of the University of Tasmania.

3.1 The study hypotheses

3.1.1 The pilot study

The pilot study tested the protocol and the robustness of the Linear Excursion Measurement Device. It also tested hypotheses that

- *there was good agreement between measurements taken on four consecutive days of cervical excursion angles;*
- *the measure of cervical excursion was stable...*

3.1.2 The reproducibility study

The reproducibility study tested hypotheses that:

- *the headache identified by the diagnostic tool had stable characteristics;*
- *events of headache, identified by the diagnostic tool, occurred with consistent frequency in consecutive months;*
- *measurements of explanatory variables were stable and in good agreement when taken one month apart.*

3.1.3 The prevalence study

The main study determined the prevalence of headache specifically associated with cervical factors. It also tested the hypothesis that:

- *there was an association between headache and the angular excursion of anatomical points on the proximal and distal aspects of the cervical spine.*

3.2 The study sample

3.2.1 The source of the subjects

The source of subjects was from the municipal electoral rolls of two adjacent municipalities in Tasmania, Australia: the Huon and the Esperance Municipalities. These municipalities were located forty and eighty kilometres respectively south of Hobart, the state capital. In 1991, the Huon municipal electoral roll contained approximately 4,500 eligible voters (individuals over the age of 18 years) and the Esperance roll contained approximately 3,800 eligible voters. Transport into these municipalities was by road, water or light aeroplane. The primary industries were timber and farming (pome and berry fruit, fish, cattle and sheep). The population of the municipalities was stable; many of the inhabitants were descendants of pioneers in the district and were employed locally.

3.2.2 The subjects

The individuals who were invited to participate in this study were selected using random numbers, proceeding backwards from the end of one electoral roll, and downwards from the beginning of the other. In the event that the chosen individual could not be contacted by telephone or letter, the next person on the electoral roll was contacted. The concept of the study was explained over the telephone to these individuals. Once individuals agreed to participate in the study, they were questioned about the exclusion criteria¹.

¹. Individuals were excluded from the study if they recalled sustaining a specific neck injury.

They were also excluded if they were taking medication for classic migraine headache, if they had known degenerative spinal conditions, if they were regularly taking anti-inflammatory medication and/ or analgesics, or if a woman was pregnant or breast feeding.

3.2.3 Sample sizes

3.2.3.1 The pilot study

Twenty subjects were involved in the pilot study. The size of this sample was calculated on the probability of 0.5 that the device's measurements were stable and in good agreement (Fleiss 1981). This sample was small however, and while it enabled the device to be trialed in a preliminary fashion, further study on the reproducibility of the measurements was required in a larger sample.

3.2.3.2 The prevalence study (the main study)

The sample size for the prevalence study was calculated using formulae described in Snedecor and Cochran (1967). At power of 80 percent and a *p* value of 0.05, 425 individuals were required to detect a prevalence of headache of 20 percent. This value was suggested by Hult (1954) from studies on headache, working posture and occupation. The first one hundred subjects in the prevalence study (23.4 per cent of the study sample) were invited to participate in a reproducibility study, for which they provided a second set of measurements one month after the initial measurements were taken. While this was a relatively small sample, one hundred subjects was the maximum number able to be re-tested within the cost and time constraints of the study.

3.2.3.3 An independent sample of subjects

One outcome of this study was a predictive scoring model for headache. 'The value of a predictive model will be overestimated if it is tested only on the data set from which it is derived' (D'Espaignet et al 1990). Thus it was planned to test the model on an independent sample of subjects (Fletcher et al 1988). Time and cost constraints limited the independent sample to fifty.

3.2.3.4 The total study sample

In total, 523 individuals were invited to participate in this study. After refusals and exclusions, 490 subjects were enrolled³.

- Twenty-three individuals were invited to participate in the pilot study. Two failed to meet the criteria and one potential subject refused to participate. The twenty remaining subjects constituted Set A in Figure 3.1.
- Four hundred and fifty individuals were invited to participate in the prevalence study. Fourteen individuals failed to meet the criteria and nine potential subjects refused to participate. The remaining 427 subjects constituted Set B in Figure 3.1.
 - The first 100 of these 427 subjects were invited to participate in the reproducibility study. Seven subjects did not return for re-measurement. The 93 remaining subjects constituted Set B1 in Figure 3.1.
- Fifty individuals were invited to participate in the study to test the predictive model for headache. Seven individuals were excluded because they failed to meet the criteria. The remaining 43 subjects constituted Set C in Figure 3.1.

The three groups of subjects, the relationship of the groups to each other and to the population from which they were selected, is illustrated in Figure 3.1.

³. The losses to the study sample (the refusals and the numbers in each exclusion category) are listed in Table 3.1.

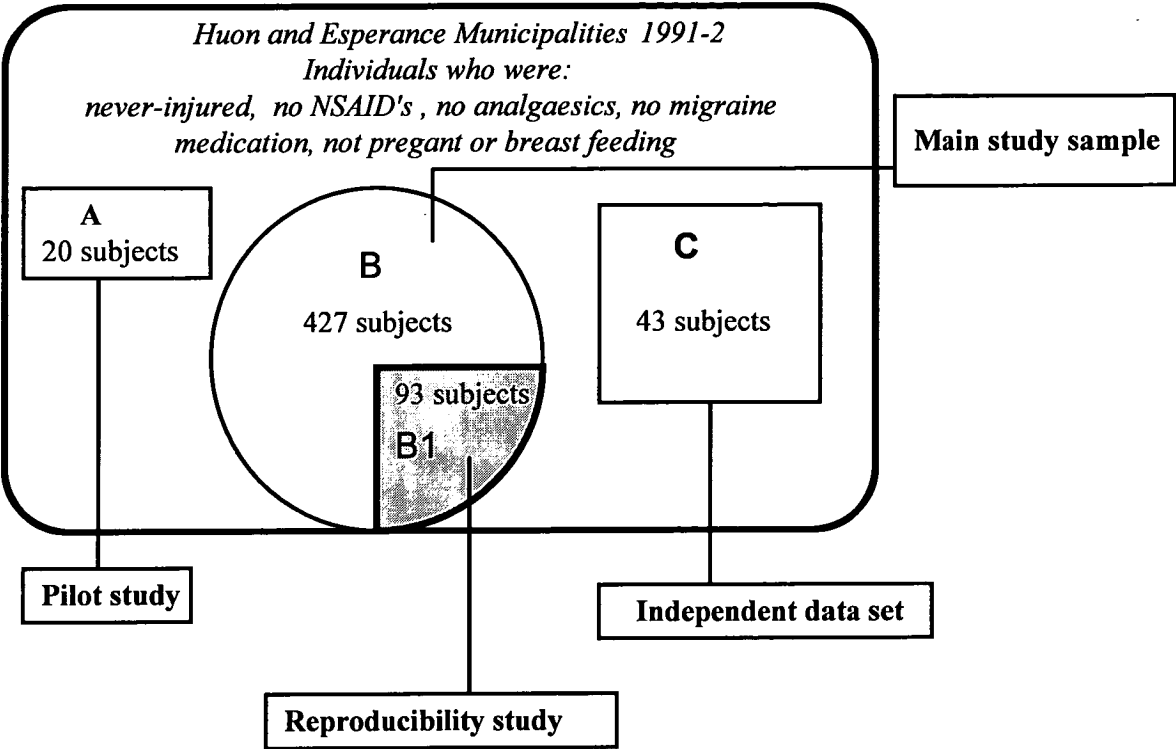


Figure 3.1. The sets of study subjects and the role of each in the study

Table 3.1. The loss of individuals to the study

	Set A	Set B	Set B1	Set C	Total
					Losses
Refusals	1	9	7	0	17
Exclusion factors					
• previous neck or back injury	0	5	0	2	7
• pregnancy or breast feeding	1	3	0	2	6
• Non Steroidal Anti-inflammatory	1	4	0	2	7
Drugs (NSAID's) or analgesics					
• Medication for migraine headaches	0	2	0	1	3

3.2.3.5 Preliminary testing

1. The representativeness of Subset B1 of the remainder of the prevalence study sample (Set B - Subset B1) was tested by determining differences in mean headache frequency and excursion angles. No significant differences were found⁴, supporting Subset B1 as representative of the remainder of the study sample.
2. There were significant gender differences in the prevalence study sample (Set B) for headache frequency, cervical excursion angles, and the anthropometric and functional variables that were identified in Chapter Two as other potential causes of headache.

The analysis used in preliminary testing is described in Section 3.7.

3.3 The method of collecting data

3.3.1 Consent

Subjects verbally agreed to participate in the study at first contact, and a suitable appointment was then made for measurement. Subjects signed a standard consent form⁵ at this appointment. All data were collected at the one central location. Subjects agreed to be identified by name on a master list (containing identification numbers and contact details) for ease of later recall. This list was destroyed when data collection was complete.

3.3.2 The pilot study (Set A in Figure 3.1)

The twenty subjects in the pilot study provided four sets of posture measurements (one measurement taken on each of four consecutive days). These measurements were taken using the protocol described in Section 3.5. Consecutive day measurements were used in an attempt to minimise within-subject variation in resting posture (Wägenhausen 1971). The time of day on which testing occurred was not controlled because of subject availability. The results of the pilot study are reported and discussed in Chapter Four.

3.3.3 The prevalence (main) study (Set B in Figure 3.1)

3.3.3.1 Sequence of testing

Testing in the prevalence study was undertaken using a standard sequence. The prevalence (main) study design is illustrated in Figure 3.2. All 427 subjects completed a written questionnaire on their arrival and no coaching was provided. The questionnaire was collected by the first scribe, and neither the second scribe nor myself viewed it at this time. Subjects then moved into the testing room. Here, the objective measurements were taken in a standard order by myself, using standard verbal instructions for each measure. No practising was permitted, in an attempt to minimise the possibility of learnt responses. The objective measurements were recorded on a sheet, separate to the questionnaire, by the second scribe, as testing was taking place.

3.3.3.1 The questionnaire

The questionnaire collected retrospective information on headache frequency within the previous month. It also collected information on social, emotional and physical variables.

3.3.3.2 The objective measurements

Subjects' height and weight were measured first, followed by their cervical excursion. Then followed the measurements of the neck column (front then back length, then circumference), the range of cervical movement measurements (left, then right lateral flexion, followed by extension). Lastly the cervical muscle performance measurements were taken (cervical flexor, then extensor strength, followed by cervical short flexor endurance).

3.3.3.3 On completion of the first measuring session

All subjects were given a copy of the diagnostic tool for headache⁵ for use in the following month. The questionnaire and the objective measurements were collated after the subject's departure by the scribes.

3.3.3.4 Prospective data collection

For the next calendar month, all subjects were asked to record on a diary any episode of headache that was described by the diagnostic tool. All subjects were made aware that they may be recalled at the end of a month for retesting. The first one hundred subjects to be tested were recalled (these subjects constituted Subset B1 in Figure 3.1), and all other subjects were contacted one month after their initial measurement session to thank them for their participation, and to tell them that they were no longer required for the study. All subjects' names were deleted at this point from the test documents, and subjects were informed that this had occurred.

3.3.4 The reproducibility study (Subset B1 in Figure 3.1)

Returning subjects answered a subsection of the original questionnaire (again without coaching) and returned their headache diary to the first scribe. A second set of objective measurements was taken and recorded in the same manner as the initial measuring session. Questions were not asked about headache occurrence; rather the information on the headache diary was transcribed onto the questionnaire by the scribes after the subject's departure. At no time during the second measurement session did I sight the test documents. The questionnaire and measurement sheet were collated by the scribes after the session.

4. The results of preliminary testing are reported in Appendix One.

5. All test documents are provided in Appendix Two.

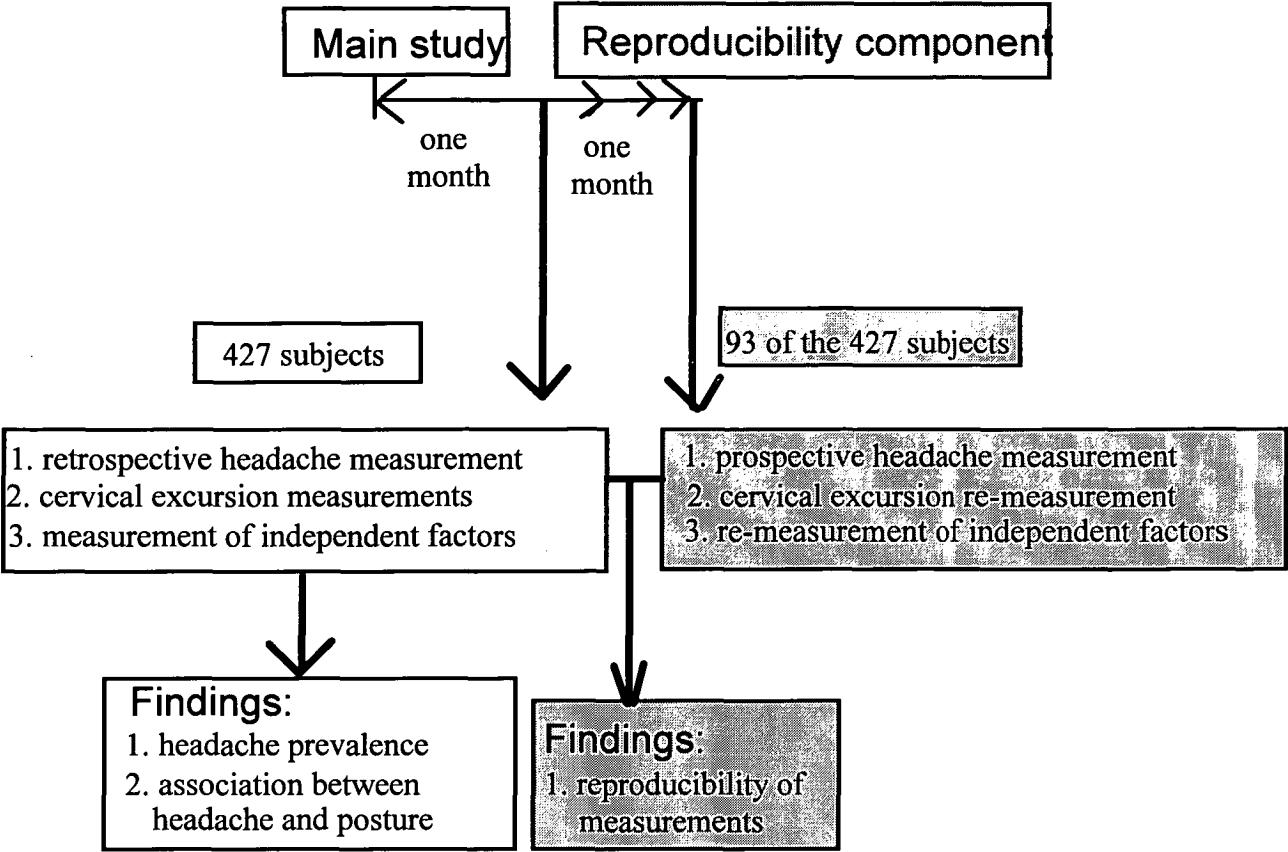


Figure 3.2. The prevalence (main) study design

3.3.5 The independent sample of subjects (Set C in Figure 3.1))

Subjects for the independent sample were selected using the same methodology as for the pilot and prevalence study. The same exclusion criteria were applied. Measurements were taken from the subjects in Set C in the same manner as the prevalence study. The data provided by subjects in Set C were not investigated until analysis of the prevalence study data was finalised.

3.3.6 The practical requirements of this study were:

- the assistance of two scribes who were unaware of the study hypotheses
- an adjustable treatment plinth
- a stop watch
- a ruler and a tape measure
- a height marker
- a set of scales
- the Linear Excursion Measuring Device
- a cervical goniometer, and
- approximately twenty minutes per subject to complete the tests.

3.3.7 Data entry

Cost constraints precluded the use of an independent data enterer. Files in Epiinfo Version 5 (Epiinfo Version 5 Users Guide 1991) were used to store the data. Four separate files were constructed:

- File 1: the test data on the (20) subjects in the pilot study (Set A)
- File 2: the first and second measurements on subject in the reproducibility study (Subset B1)
- File 3: the test data for the (427) subjects in the main study (Set B)
- File 4: the test data for the set of (43) independent subjects (Set C).

3.4 Measuring headache frequency retrospectively

3.4.1 The construction of the headache frequency scale

A horizontal line was drawn to represent one month, or 31 days. The centre point of the line was identified as the frequent headache threshold of two headaches per month cited by Edeling (1988) and Watson and Trott (1991), on the grounds that two headaches per month represent one headache occurring approximately every half month. Minimum headache occurrence (none) and maximum headache occurrence (daily) were sited at the extremes of the line. The time intervals between zero and two, and between two and thirty-one occurrences per month, were divided into equal portions. This process limited the scale to seven categories because of the finite time division between zero and two headaches. The seven divisions of the scale were nominally described for questionnaire purposes. The process of constructing the scale is illustrated in Figure 3.3.

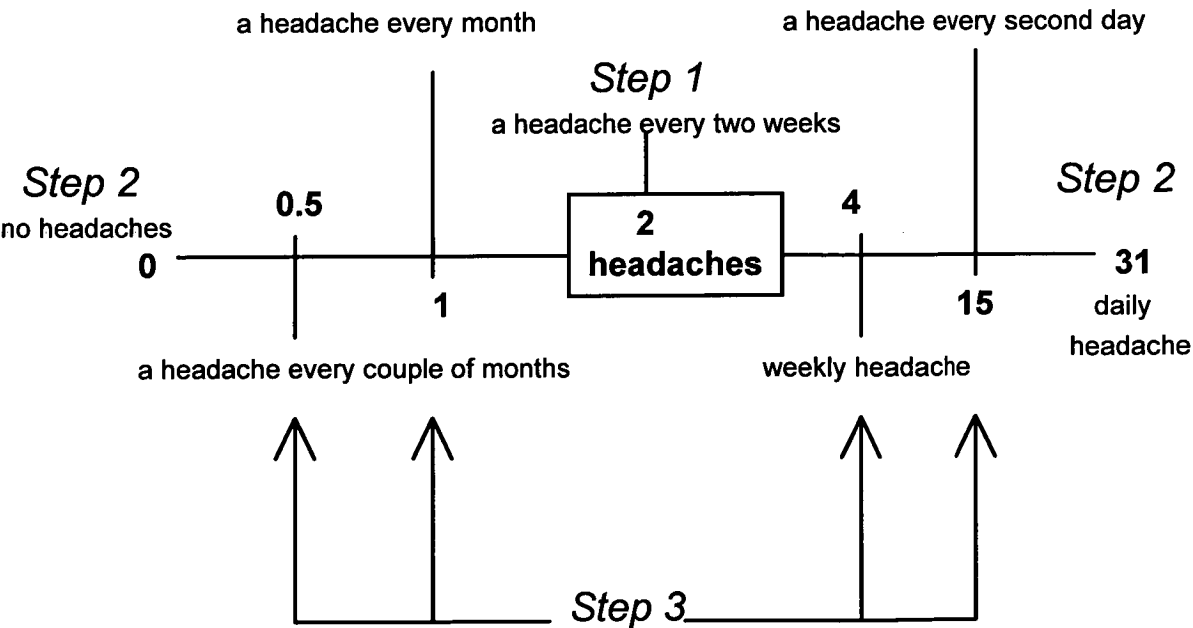


Figure 3.3. The process of constructing the headache scale

3.4.2 Diagnosis and recording

Headache information was recorded in two ways in the questionnaire. If any event of headache, that was described by the diagnostic tool, had occurred in the month preceding the initial measurement session, the subject recorded Yes in a Yes/No question. The frequency with which headache occurred was then recorded on the nominal scale.

3.4.3 Scoring the scale

1. Comparing retrospective and prospective data on headache frequency

Each category of the nominal headache scale (retrospective measurement) was assigned a value appropriate to 'days of headache per month'. This was done in order to compare retrospective headache information with the actual number of headaches recorded in the headache diary (this being the second (prospective) measurement of headache frequency supplied by Subset B1). Such comparison enabled investigation of the consistency with which headache was reported over two months of testing. Scoring the nominal scale in this way described the frequency of headache in patient-oriented terms that were appropriate for a clinical setting (Melzack 1975). The categories of none, and every few months, monthly and daily headache were assigned the values of 0, 0.5, 1 and 31, which appropriately described them in 'days per month of headache'. The remaining categories (twice monthly, weekly and twice weekly) were assigned two sets of scores in an effort to examine, and minimise, the variation inherent in assigning one score to a time range. Values representing the nominal descriptive category (2, 4 and 15 headaches) were assigned to the categories of twice monthly, weekly and twice weekly. Values representing the midpoint of the range of each category (3, 9.5 and 22.5 headaches) were also assigned to these categories.

This second set of scores were assigned in the manner described by Cramer (1991) and Rothman (1986). The scoring methods are contrasted in Figure 3.4.

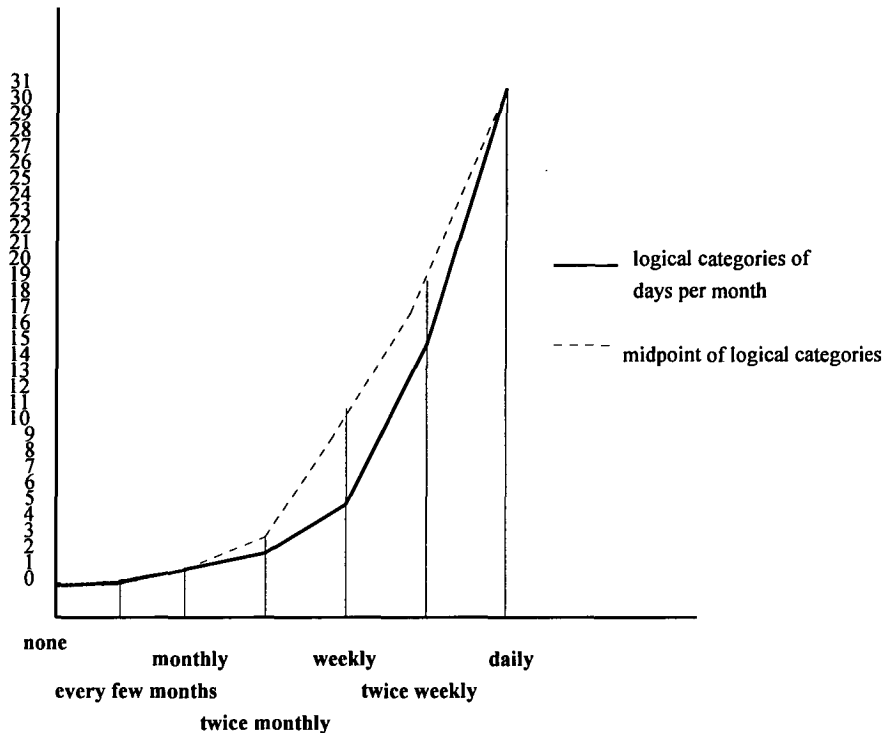


Figure 3.4. The two scoring methods of the nominal headache scale

The shape of the scale was relatively unaffected by the scores assigned to the categories of twice a month, weekly and twice weekly. The inherent variability in the scale was also unchanged. On this evidence, the first method of scoring was adopted, because it was more appropriate in a clinical setting, in that it was more readily understood by patients. The null hypothesis underpinning the comparison of retrospectively-reported and prospectively-recorded headache anticipated that for each subject, the number of prospectively-reported headaches fell within the range of the retrospectively-reported headache category.

The method used to compare the retrospective and prospective data is described in Figure 3.5, with 'best case' results reported.

<div>scale</div> <div>diary</div>	none	every few months	monthly	twice monthly	weekly	twice weekly	daily
	0	0.5	1	2	4	15	31
0 H/A	100%	50%					
1 H/A		50%	100%				
2-3 H/A				100%			
4 -14 H/A					100%		
15-29/30						100%	
30, 31 H/A							100%

Figure 3.5. 'Best case' results and the method of comparison of retrospective and prospective headache data (H/A = headache)

2. Preliminary investigations into the association of headache with its causes

The nominal headache scale also required a numeric score in order that preliminary investigations could be conducted into the nature of association between headache and its causes. The 'days per month of headache' score for the nominal scale was inappropriate for this purpose because of its inherent variability. The proposed headache causes were on the whole, parametric variables, and preliminary investigations required the use of linear regression models and tests of differences in means. The Ordinary Least Squares model that underpins the linear regression procedure assumes a normal distribution of the error term (Schlotzhauer and Littell 1987). Such a distribution was not available from the 'days per month of headache' scores

as described in the previous section. A Normal distribution of the error term can be approximated however, by assigning ordinal scores to a nominal scale (Agresti 1984, Knapp 1990, Lipsitz 1992, McDowell and Newell 1987, Streiner and Norman 1989). In a case where no previous scoring method has been developed, Miettinen (1985) suggests the development of 'a minimal set of indices*a priori*, where a standard indices is not available' (p. 25-26). The nominal headache categories were scored in ranked order, one to seven. This scoring system is described in Figure 3.6.

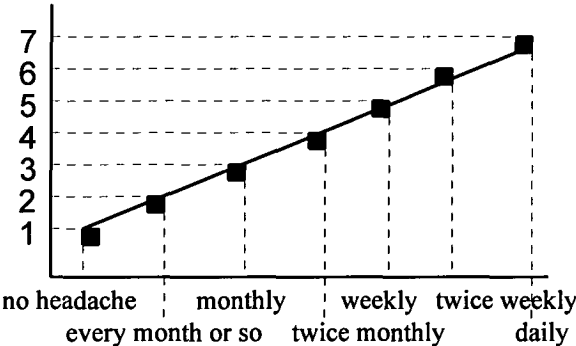


Figure 3.6. The ordinaly-scored headache scale

3.4.4 Headache morbidity

This study provided the opportunity to describe the morbidity of headache associated with cervical factors in the never-injured population.

3.4.4.1 Symptoms associated with headache

Information was sought from headache sufferers by the first scribe, about the remaining four of Jull's pain criteria (Criteria 1, 3, 4 and 7), which were not specific to headache associated with cervical factors. For ease of administration, colloquial descriptors of them were developed⁵. In the questionnaire, all subjects were asked to report on occurrences of stiff and/or aching necks in the month preceding the measurement session.

3.4.4.2 Pain management

Each headache sufferer was asked in the questionnaire to record the usual method of headache management, using categories that were established from clinical experience and the literature (Edeling 1988, Jull 1981, 1986). One category was for regular medication. Medication has been employed in studies on spinal pain as a measure of pain intensity and physical and mental health (Foreman and Croft 1988, Strang 1985, Troup 1988). The type of medication was recorded by the subject as text, and coded later by myself using the Pharmacological and Therapeutic Index (1987).

3.4.4.3 Precursor functional activities

Subjects were asked in the questionnaire to describe the functional activity that most frequently preceded headache described by the diagnostic tool. This was recorded as text and grouped at a later date by myself into categories of similar biological action. This information enabled the nature of cervical influences on headache to be more fully described. The functional activities and the groups into which they were assigned, are described and discussed in Chapter Seven.

3.5 The measurement of cervical resting posture

A device that measured cervical excursion was designed and manufactured in a collaborative effort among my family, colleagues and myself. The Engineering Department of the Royal Hobart Hospital assisted in the final construction stages.

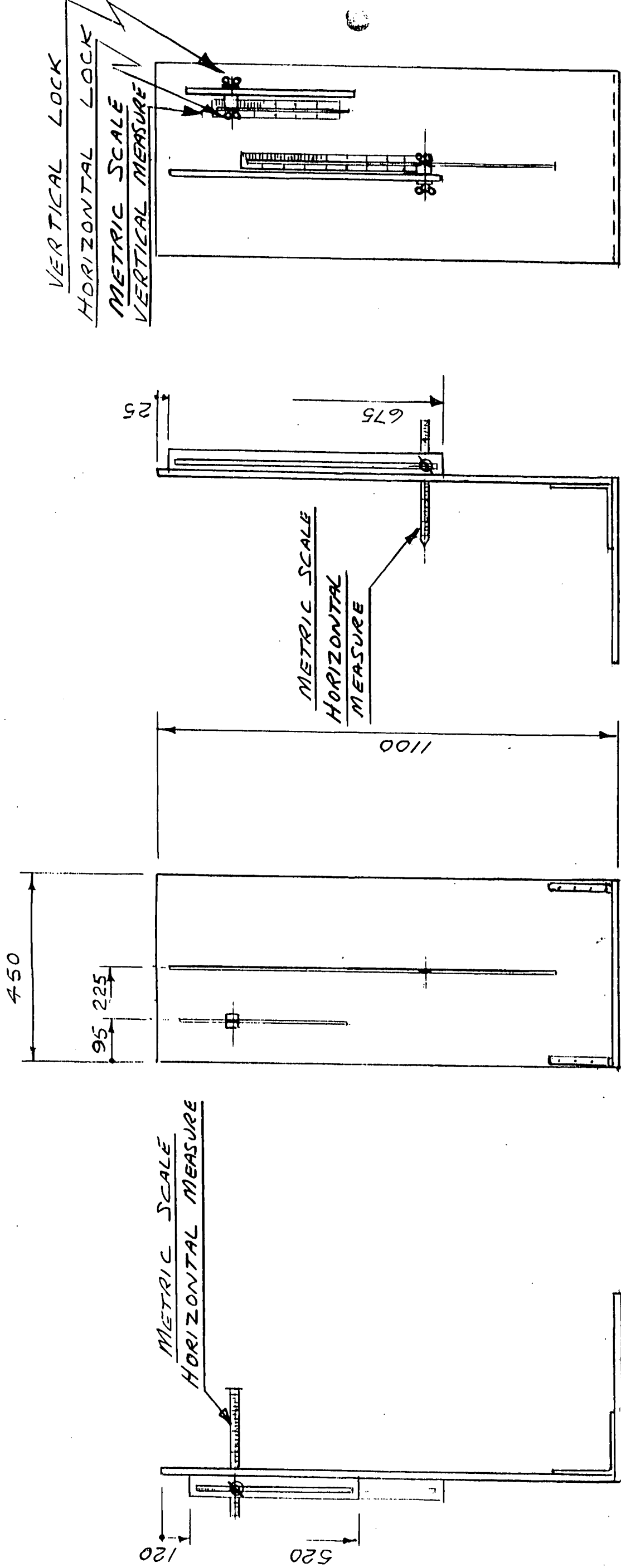
The instrument was named the Linear Excursion Measurement Device (LEMD). It measured the horizontal and vertical excursion traced by a proximal and a distal anatomical point on the cervical spine. The linear measurements were combined and expressed as angles of excursion for each anatomical point using the formula:

$$\text{degrees} = \tan^{-1} \frac{\text{vertical distance}}{\text{horizontal distance}}$$

Small angles of excursion were produced by small vertical excursion movements and large horizontal excursion movements of the anatomical point. Large angles of excursion of the anatomical point were obtained when the vertical movement increased and the horizontal movement decreased.

3.5.1 The design of the Linear Excursion Measurement Device

The LEMD consisted of a vertical backboard attached at right angles to a horizontal board seat. Two vertical slots were cut, one into the centre of the backboard, and one fifteen centimetres to the right of this slot. A frame fitted parallel to each slot on the rear of the backboard accommodated a sliding T-square bracket. A casing, mounted onto this bracket, allowed a calibrated steel ruler to run through the vertical slot. Each casing had two screws: one to lock the T-square bracket onto the frame, and the other to lock the ruler into position within the casing. A millimetre ruler with a sliding central pointer was placed parallel to each vertical slot on the rear of the backboard. This device is illustrated in Figure 3.7.

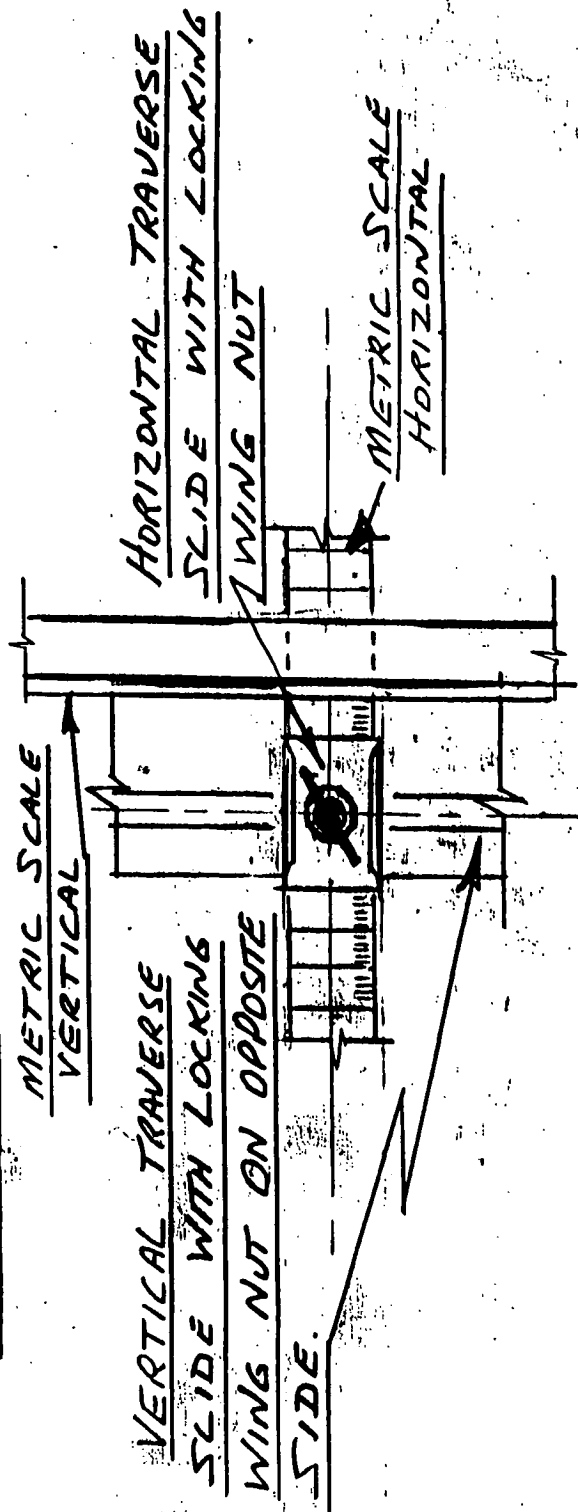


RIGHT SIDE

FRONT VIEW

LEFT SIDE

REAR VIEW



POSTURE MEASURING DEVICE
LAYOUT & DETAIL

SCALE - 1:10 & 1:2

Figure 3.7. The blueprint for the Linear Excursion Measurement Device

3.5.2 Anatomical reference points

The **superior-most tip of the helix of the ear** was chosen as the reference point for upper cervical spine movement because it was clearly visible, it moved in direct relation to the skull and it could be indelibly marked for re-measurement. This point was closely aligned with the Kendall et al (1952) vertical reference line when it passed through the upper cervical spine. This was considered to be the distal point on the cervical spine, because it was the furthest from the body centre (Panjabi 1974). The **spinous process of C₇** was chosen as the reference point for lower cervical spine movement, because it could be located by sight and palpation. It was a choice consistent with the method of measuring cervical posture using the cranio-vertebral angle (Braun and Amundsen 1989).

3.5.3 Measurement Protocol

The LEMD was positioned on an adjustable plinth which allowed each subject to sit with thighs, knees and ankles at 90 degrees. Subjects' forearms rested comfortably on their thighs. The anatomical reference points at the superior-most tip of the helix of the ear, and the spinous process of C₇ were marked. Subjects were verbally instructed using a standard protocol in the method of measuring cervical excursion. They were not allowed any practice time to minimise the possibility of learnt responses. A wall chart hung on the wall in front of the subjects, and subjects were asked to spot any letter. They then maximally retracted their chins and pressed the back of their head as well as their shoulder blades on to the vertical backboard. This procedure standardised the starting position, despite the wide range of chin retraction mobility observed among subjects. The maximal chin retraction position was described by Braun and Amundson (1989), and McKenzie (1990). The horizontal rulers were positioned level with the reference points, and the position of the T Square was marked on the vertical ruler (Figure 3.8a).

Subjects then assumed their usual cervical resting posture using the Natural Head Posture technique (Solow and Tallgren 1971). This involved flexing and extending the head in three decreasing amplitude movements, with the head coming to rest in its habitual resting position. During this procedure, subjects maintained contact between the inferior aspect of their scapulae and the backboard, and spotted the selected letter during each head sweep. The usual resting posture of the head was measured by sliding the T squares down and again fixing the horizontal rulers level with the marked anatomical points (Figure 3.8b). The use of standard instructions for eye contact during the three sweeps of the head was considered to be an important element of the protocol, as tonic coupling has been observed between horizontal eye position and dorsal muscle activity in both humans and animals (Andre-Deshays et al 1991). A relationship between eye activity, neck muscle performance and head movement standardised the horizontal placement of the head during assumption of habitual resting posture (Hanten et al 1991, Solow and Tallgren 1971).

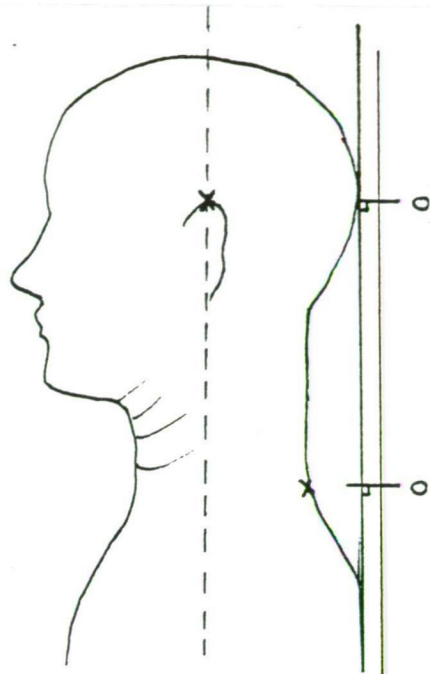
A chest strap advocated by Braun and Amundson (1989) to isolate cervical resting posture measurements was not employed with this device. There was concern that a chest strap might disadvantage the true excursion of C₇ by unduly constraining the usual relaxation of the lower cervical and upper thoracic spine. Mid-thoracic stability was confirmed by continued contact between the inferior aspect of the scapulae and the vertical backboard during all movements. Operating without a chest restraint in this study, it was found that all subjects achieved sufficient shoulder relaxation after the initial head flexion movement, to allow the head to lie anterior to the vertical backboard at the full arc of initial extension. The process of measuring the excursion angles is illustrated in Figures 3.9a and 3.9b. The cervical resting postures associated with different excursion angles are provided for interest.



Figure 3.8a. The starting position for measuring cervical excursion: with the head and neck in a corrected vertical position



Figure 3.8b. The final position for measuring cervical excursion: with the head in its usual resting position



$$\theta_{\text{helix}} = \tan^{-1} \frac{d1}{d2}$$

$$\theta_{C7} = \tan^{-1} \frac{d3}{d4}$$

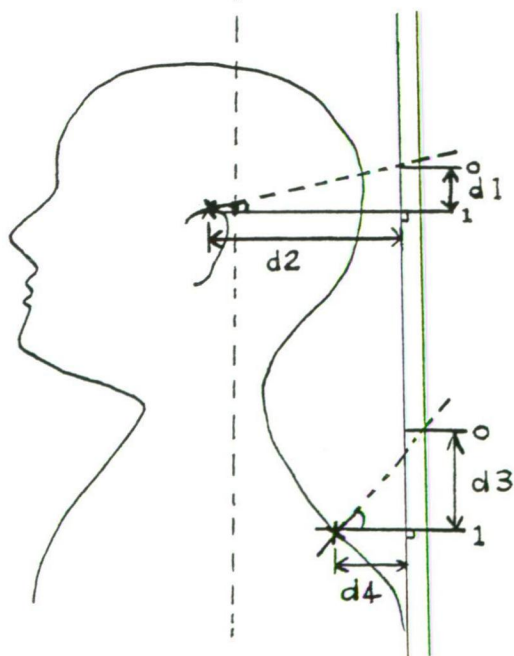
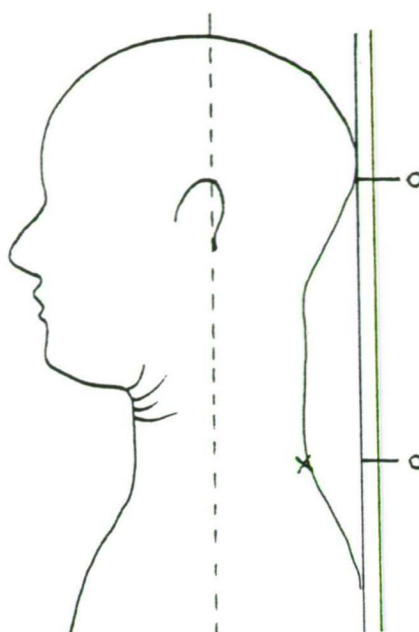
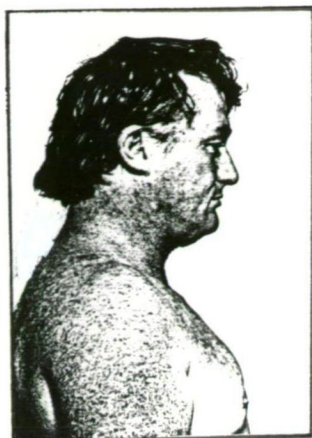


Figure 3.9a. The process of measuring a subject with large excursion angles occurring at both the helix and C₇.



$$\theta_{\text{helix}} = \tan^{-1} \frac{d1}{d2}$$

$$\theta_{C7} = \tan^{-1} \frac{d3}{d4}$$

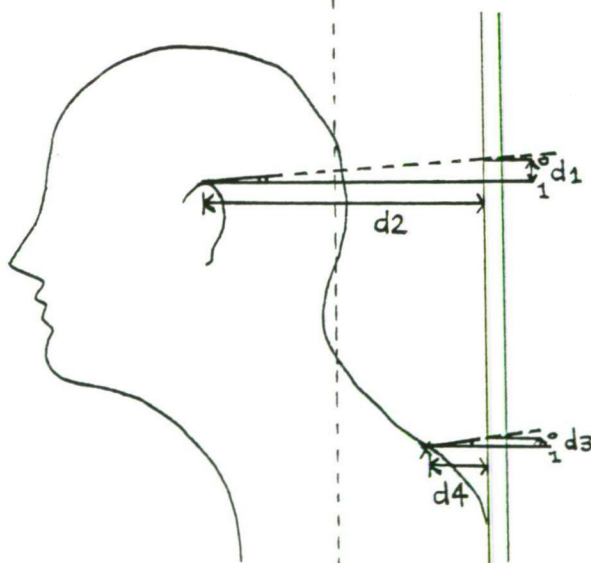


Figure 3.9b. The process of measuring a subject with small excursion angles occurring at both the helix and C₇.

3.6 Measuring other causes of headache

3.6.1 By questionnaire

Gender and age

Gender, birth date and the date of testing were recorded, and age was later calculated by subtracting birth date from the date of testing. The date of birth was recorded in preference to a self report of age, in order to minimise inaccuracies in reporting.

Breast size

Women recorded information on brassiere cup size and chest circumference. Brassiere cup size was employed in this study as a proxy for breast size (and therefore breast weight). Brassiere cup size was sized using alphabetic characters, where A was the smallest cup size and D was the largest cup size.

The effect of the menses

Women recorded in Yes/ No statements whether they usually suffered problems with premenstrual tension, and whether they usually associated aches or pains with their menstrual cycle.

Occupation within the last month

Occupation was recorded by the subject as free text. This was coded by myself before data entry, using the Australian Standard Classification of Occupations (ASCO) codes (Australian Bureau of Statistics 1984). The primary occupational codes and their descriptions are summarised in Table 3.2. House persons were recorded as Domestic Managers under the code 1000.

Table 3.2. Occupation codes used in the study

Type of Occupation	ASCO Codes
Managerial	1000 - 1999
Professional	2000 - 2999
Para professional	3000 - 3999
Trades persons	4000 - 4999
Clerical	5000 - 5999
Service Industry	6000 - 6999
Plant Operators	7000 - 7999
Labourers	8000 - 8999

Ninety-six per cent of subjects were engaged in an occupation in the month prior to the study, with 72.5 per cent of them employed in a full time capacity. For the purpose of analysis, occupation was considered in three broad categories because of small numbers of para professionals, service workers and plant operators in the study sample. The broad categories were based on like physical activity. They were managerial/ professional occupations (encompassing ASCO codes 1000 - 3999), clerical/ service workers (encompassing ASCO codes 5000-6999) and blue collar workers (encompassing trades persons, plant operators and labourers, ASCO codes 4000-4999, and 7000-8999).

Wearing glasses

Subjects recorded whether they wore glasses, and for what reason. Gender was considered an unlikely influence on the prevalence of wearing glasses. The categories of wearing glasses, and the number of subjects in each, are listed in Table 3.3.

Table 3.3. The number of subjects wearing categories of glasses

Reason for wearing glasses	<i>n</i>
for reading	106
for distance vision	12
all the time	96
Total	214

Wearing dentures

The type of dentures worn by subjects was recorded as free text, and assigned as categories at a later date. The denture question was approached in this manner (and not categorised before-hand) because the variety of types of dentures worn by subjects was unknown. Gender was also considered an unlikely in the prevalence of wearing dentures. The number of subjects in each category of dentures is reported in Table 3.4.

Table 3.4. The types of dentures, and the numbers reporting each type

Denture type	<i>n</i>
partial top dentures	27
full top dentures	31
partial bottom	13
full bottom	20
partial top and bottom	88
full top and bottom	31
Total	210

Emotional Wellbeing

Emotional wellbeing was measured using the General Wellbeing Schedule (Dupuy 1978). This was completed by the subject as part of the questionnaire⁵. The General Wellbeing Schedule sums the scores of measures of anxiety, depression, vitality, self control, wellbeing and health over the preceding month. As the six individual elements in the Schedule have few items, they are considered on their own, to be crude measures only of attitudinal behaviour (Fazio 1977). The Schedule was developed for the United States of America Health and Nutrition Examination Survey (HANES) as a 'brief but broad ranging indicator of subjective feelings of psychological wellbeing and distress for use in community surveys' (McDowell and Newell 1987 p.125).

The validity of the Schedule has been demonstrated by fair to good correlation with other scales (Brook et al 1979, Fazio 1977, Simpkins and Burke 1974). Two of the elements measured in the Schedule (anxiety and positive wellbeing) have been shown to be reliable on re-test after one week (Dupuy 1978), and the reliability of the summed scores of the six elements has been demonstrated over a three month period (Monk 1981, Fazio 1977). However, considerable within-subject variability has been observed in measurements of each of the individual elements over the interval of a month, where the correlation statistic has been reported to be in the order of 0.50 (Ware et al 1979).

For the purpose of this present study, the Schedule was expressed as the summed scores of the six elements. This decision was taken because of the high internal consistency between individual elements, the potential redundancy of the individual measures and the crude nature of the instrument resulting from the small number of items in each element (Fazio 1977, Wan and Livieratos (1977). Table 3.5 summarises the component questions and the scores for each element of the Schedule.

Table 3.5. Components of the General Wellbeing Schedule

Anxiety	Depression	Vitality	Self control	Health	Wellbeing
the sum of	the sum of	the sum of	the sum of	the sum of	the sum of
Q2.	Q4.	Q9.	Q3.	Q10.	Q1.
nervousness	sadness	waking fresh	firm control	bodily	feeling about life
(scored 1-6)	(scored 1-6)	(scored 1-6)	(scored 1-6)	disorders	in general
				(scored 1-6)	(scored 1-6)
Q5.	Q12.	Q14.	Q7.	Q15.	Q6.
strain	down-hearted	feeling tired	losing control	health worries	happiness
(scored 1-6)	(scored 1-6)	(scored 1-6)	(scored 1-6)	(scored 0-10)	(scored 1-6)
Q8.	Q18.	Q17.	Q13.		Q11.
anxiety	depression	energy level	emotionally		interesting daily
(scored 1-6)	(scored 0-10)	(scored 0-10)	stable (scored 1-6)		life (scored 1-6)
Q16.					
relaxation					
(scored 1-10)					

3.6.2 By objective measurements

Height and Weight

Height was measured using a fixed vertical tape measure. The subjects stood without shoes against the tape, with their eyes level and chin retracted. Weight was measured in kilograms using the one set of bathroom scales. Subjects were weighed fully clothed but without shoes. The scales were correlated against electronic scales situated in the Medical Section of the Hobart Branch of the Department of Veterans Affairs. The bathroom scales were found to measure in accordance with the electronic scales.

Neck Column

Measurements of neck column were taken with a flexible non-stretch centimetre tape measure with the subject's head positioned in line with a vertical axis. Tape measures provide precise measurements when they are made of a material that does not stretch and when remeasure is facilitated by the use of landmarks (Amarasinghe 1966). Circumference of the neck was measured by placing the tape measure around the neck at the level of the base of the glottis and spinous process of C₇. The length of the front of the neck was measured from the point of the chin, along the front of the neck to the notch of the zyphisternum. The length of the back of the neck was measured from the bony occipital prominence on the skull to the spinous process of C₇. The reproducibility of the measurements of the length and circumference of the neck column is addressed in Chapter Five.

Range of cervical movement

Gross cervical lateral flexion and extension range of movement were measured with a cervical goniometer, which has been reported as a reliable measure of cervical range of movement by Kadir et al (1981) and Klaber Moffatt et al (1989). The test procedure that was described by Klaber Moffett et al (1989) was used in this study. Use of the same head strap position for all measurements minimised measuring time. No practice was permitted. To measure lateral flexion, subjects were asked to maintain eyes front, and bend their heads to the left, and then to the right, as far as possible without discomfort. Measurements were taken at the extremes of range. the two measurements were averaged for analysis purposes. While differences between unilateral ranges of lateral flexion movement may have provided clinical evidence of underlying unilateral cervical dysfunction (Dvorak et al 1987), this study was only able to examine an association between overall lateral flexion range of movement and headache, because of the

retrospective measurement of headache frequency. To measure extension, subjects were asked to bend their head and neck back as far as possible without discomfort, without moving their thoracic spine or the position of their trunk. The extension measurement was taken at the extreme of possible range. There was moderate correlation between mean lateral flexion and extension range of movement for both men and women (correlation coefficient for men = 0.67 ($p < 0.05$), for women = 0.63 ($p < 0.05$)). The reproducibility of the range of movement measurements is addressed in Chapter Five.

Muscle performance

The bilateral strength of the cervical flexors (CFS), and then the cervical extensors (CES) was measured with bilateral antigravity and manual resistance tests in the manner described by Janda (1983b). Janda's test procedures were employed because they were comprehensively illustrated, they were widely employed in clinical settings by Australian physiotherapists, and they were appropriate for non-injured subjects (Stolov 1982). The Janda muscle tests (1983b) scored muscle strength in five nominal levels that were assigned equal interval scores. While manual muscle testing has face and content validity, its reliability has not been adequately tested and the validity of the interval scores has not been established (Lamb 1985). As for all other measurements, no practice time was allowed.

An objective measure of the endurance of the cervical short flexor muscle group (CSFME) was developed for this study because none was available in a clinical setting. The new measure was based on an exercise position described by Trott (1988) to improve the isometric performance of the cervical short flexors. Verbal instructions were given prior to the subject undertaking the movement, and no practice time was allowed. Subjects lay supine on a

plinth and retracted their chins. This position is illustrated in Figure 3.10a. Subjects then lifted their heads approximately two centimetres from the plinth. This movement was controlled using a vertical ruler placed against the subject's temple. This position is illustrated in Figure 3.10b. The time between assuming the test position until the chin began to thrust was measured in seconds with a stop watch. Chin thrust is reported to be associated with failure of the short cervical flexor muscles (Janda 1988, Richardson 1989). The moment of chin thrust was determined both by the author's observation, and light finger pressure under the chin. The anti-gravity endurance capacity of the cervical short flexors was reported in seconds. The reproducibility of the muscle performance measurements is addressed in Chapter Five.



Figure 3.10a The starting position for measuring cervical short flexor endurance



Figure 3.10b. The test position for measuring cervical short flexor endurance

3.6.3 Relationship between cervical muscle performance measures

The relationship between measures of cervical muscle performance, and their contribution to head-on-neck posture, has not been well described. There is a common clinical belief that poor cervical short flexor muscle endurance (CSFME) and poor cervical extensor strength (CES) are both associated with poor resting head posture, and that in this circumstance, long cervical flexors (CFS) overwork to control the head on the neck against gravitational forces (Richardson 1989, Sahrmann 1987, 1988). Similarly sized correlations were observed between measures of cervical muscle performance for men and women in the sample data. These are reported in Table 3.6⁶. Despite the

need, it was beyond the scope of this study to pursue a closer examination of the relationship between these measures of muscle performance.

Table 3.6. The correlation between measures of cervical muscle performance

men	CFS	CES	CSFME
CFS	1	0.47 (<i>p</i> <0.0001)	0.29 (<i>p</i> <0.0001)
CES		1	0.23 (<i>p</i> <0.001)
CSFME			1
women			
CFS	1	0.59 (<i>p</i> <0.0001)	0.33 (<i>p</i> <0.0001)
CES		1	0.19 (<i>p</i> <0.001)
CSFME			1

⁶. Correlation procedures were employed because no evidence of causality was sought (Nunnally 1972). All the correlation coefficients were reported so that judgements could be made regarding the relative relationships between variables (Rothman 1986)

3.7 Analysis of the data

The analysis of the data is described in detail in this section, and summary reference only is made to it in subsequent chapters. The World Health Organisation statistical package Epiinfo Version 5 (Epiinfo Version 5 Users Guide 1991) was used to store the data and to conduct preliminary investigations. SAS Release 6.03 (SAS/STAT Users Guide Release 6.03 1988, Schlotzhauer and Littell 1987) and Egret Version 1.00 (Egret Users Manual 1991) were employed for more detailed analyses.

3.7.1 Preliminary testing

3.7.1.1 Data checking: approximation to the Normal distribution

The frequency distribution of each parametric variable was investigated using SAS Version 6.03 Proc Univariate. Skewness and kurtosis values close to One, a Shapiro-Wilk statistic of a value close to One and a linear pattern of the residuals described a Normal frequency distribution.

3.7.1.2 Representativeness of Subset B1, and gender differences in the main study sample

The representativeness of Subset B1 of the remainder of Set B was determined by comparing mean headache frequency and mean excursion angles. Gender differences were determined for all study variables in the main study sample. Differences were identified in means of scaled variables by ANOVA and *t*-test procedures, and in categorical variables by cross-tabulation procedures in SAS Version 6.03.

3.7.2 The reproducibility of measurements

To reproduce a measurement is to 'duplicate it ... with no alteration' (The Shorter Oxford English Dictionary 1973 p. 1797). There are a number of ways of expressing the differences between two sets of scores (Armstrong et al 1992, Hall 1994, Haas 1991, Maher 1993). The words 'reliability'⁷ and 'reproducibility', commonly cited in discussions on differences between scores, appear to be largely interchangeable. Reliability has been defined in a statistical sense as 'the consistency or reproducibility of measurements; the degree to which measurements are error-free and the degree to which measurements will agree' (Rothstein et al 1991 p. 143). However, in this present study, the word 'reproducibility' was used in preference to the word 'reliability' because untested new measures were proposed (*ibid*). The reproducibility of measurements was reported as two elements: the stability⁸ of the characteristic (Nunnally 1972) and the agreement between scores (Altman and Bland 1983, Armstrong et al 1992).

Intermethod testing procedures were used to test differences in headache frequency, because it was measured by the same subjects in different ways over different time periods (Armstrong et al 1992). Intramethod testing procedures were used to test the reproducibility of measurements of all other variables, as the same test was applied to the same subjects on two different occasions by the same measurer (Armstrong et al 1992). Account therefore needed to be taken of the correlation between the error terms.

⁷. The Shorter Oxford Dictionary (1973) defines the word 'rely' as 'to put trust or confidence in a thing' p. 1790.

⁸. The Shorter Oxford Dictionary (1973) defines 'stability' as 'capacity for resistance to displacement' p. 2098.

3.7.2.1 Measures of association

The stability of the characteristic of the measure under investigation was described by the level of association between two sets of scores (Nunnally 1972). Evidence of the stability of the characteristic of the measure was particularly important in the case of the new measures of headache, cervical excursion and short cervical flexor endurance, where no precise measure was available for comparison (Carmines and Zeller 1979, Rothstein 1985).

Parametric variables

The association between test and retest scores of parametric variables was reported as the r^2 statistic, an output of the linear regression procedure in SAS Version 6.03. This statistic was an expression of the amount of variation in the test scores that was explained by the re-test scores (Maher 1993).

Non-parametric variables

The association between two sets of non-parametric scores was expressed as Kendall's tau-b and gamma statistics from the output of SAS Version 6.03 Proc Freq. These statistics expressed the association between scores in terms of ordered and tied pairs.

Internal consistency reliability

The internal consistency reliability of the General Wellbeing Schedule was examined in two ways, because of the multiple response nature of the Schedule. The first way determined the consistency within each of the six elements of the General Wellbeing Schedule: anxiety, depression, positive wellbeing, health, self control and vitality⁹. The second way determined the internal consistency of the General Wellbeing Schedule itself using the Cronbach (1951) coefficient alpha, where n is the number of items in the instrument, and reliability =
$$\frac{n (1 - \text{sum of variances of items})}{n - 1 (\text{variance of total score})}.$$

The coefficient alpha was chosen over an alternative method to demonstrate internal consistency reliability, that of the split half (the Spearman-Brown prophesy formula cited by Lindvall and Nitko 1975). The choice of the Cronbach coefficient alpha was based on the understanding that the unequal odd and even numbers of sub-items associated with the six main components invited several approaches of splitting the instrument. The resultant wide variation increased the likelihood for error when estimating reliability (Richman et al 1980). Moreover, the Cronbach (1951) formula offered a method of averaging all the split half reliability scores.

3.7.2.2 Measures of Agreement

Parametric variables

Two approaches were employed to examine the level of agreement between test and retest scores: the Analysis of Variance approach (Armstrong et al 1992) and the population mean approach (Altman and Bland 1983).

⁹. The component questions of the General Wellbeing Schedule and their scores were reported in Table 3B.

The Analysis of Variance approach

The within-subject variation was examined using an Analysis of Variance procedure under a general linear model (Proc GLM, SAS Version 6.03), where account was taken of the random subject effects between paired tests as well as any systematic error between the first and second tests.

- From the output of the ANOVA procedure, intraclass correlations ($ICC_{1,3}$) and the lower 95% confidence limits were constructed according to the formulae described in Armstrong et al (1992) (p. 100-105). The 95% confidence limits took account of the F value appropriate to the confidence limit, the degrees of freedom and the number of tests.
- The within-subject variation was expressed as a percentage of the total variation in the model where: total variation = between-subject treatment effect + within-subject effect (Armstrong et al 1992).
- The coefficient of variation (CV) was an estimation of the percentage of the mean that was accounted for by the within-subject variation (Schlotzhauer and Littell 1987).
- The root mean square error statistic (RMSE) provided a relative indication of the size of the within-subject variation.

The effect of time on the measurement of cervical excursion

The effect of time on the measurement of cervical excursion was examined using the output of Analysis of Variance procedures under a general linear model (Proc GLM SAS Version 6.03). Data from two sets of subjects were examined:

- Set A (the twenty subjects in the pilot study) and
- Subset B1 (the 93 subjects in the reproducibility study).

The largest per cent contribution of the within-subject variation to the total variation between paired day-apart tests (Set A) was identified, and compared with the percentage contribution of within-subject variation to the total variation over the month interval (Subset B1). The root mean square errors and the coefficients of variation were also compared to provide information on the relative sizes of the within-subject variation in the two data sets.

The population mean approach

1. Altman and Bland (1983) reported a method of examining the variation between test and retest scores by plotting the difference between scores against the average score. A horizontal plot indicates similar variation between scores across the range of the score. A curvilinear plot identifies places of greater than average variation between scores.
2. Where the same subjects were measured on two occasions under the same conditions (Runyon and Haber 1972, Snedecor and Cochran 1967), *t*-tests for correlated means were calculated using Proc Univariate (SAS Version 6.03). Significant differences between means identified systematic influences affecting the retest scores.

Non - Parametric variables

The level of agreement between two sets of scores was expressed as Cohen's Kappa score for binomial variables (Haas 1991, Maclure and Willett 1987) and the weighted Kappa for ordered categorical variables (Armstrong et al 1992).

3.7.3 Categories of headache frequency

The literature supports division of headache frequency into categories of none, occasional and frequent headache (Edeling 1988, Kaganov et al 1981, Mathew et al 1982, Saper 1986, Watson and Trott 1993). The separate nature of occasional headache was investigated as differences between headache categories, in functional and emotional variables. Potential misclassification of headache in categories was discussed with respect to the consistency of headache reporting by Subset B1.

3.7.4 Categorising explanatory variables

The categorical nature of headache, and the lack of biological theory underpinning knowledge of the relationship between headache and its causes suggested that the explanatory variables were best categorised for model testing purposes¹⁰. Rothman (1986) suggests that minimum modelling assumptions should be employed in such circumstances¹¹. The explanatory variables comprised parametric data (continuous and scaled) and categorical data (dichotomous and multilevel categories). In view of the lack of guidance from biological theory, it was tempting to set the cut points in the parametric data at the median value, this representing the most robust point of division by ensuring the same number of subjects in each category (Rothman 1986). However, as this was the first known population-based study into headache associated with cervical factors, it was considered important to as fully as possible, describe the nature of the relationship of headache with each proposed cause, in order to inform subsequent studies.

¹⁰. Biological relationships with headache for posture and other causes of headache were presented, on the basis of current knowledge, in Chapter Two.

¹¹. The need for appropriate Exposure terms in the model for headache were discussed in Chapter Two.

This section deals with the methods used to determine the most appropriate form of the parametric and multilevel categorical variables for modelling purposes. The parametric variables were divided into categories in the following manner¹².

Step 1. On the basis of the frequency distribution, the data for each variable were divided into quintiles (Cochran 1968, Cramer 1991). Five equal divisions in the data were constrained in some instances by the distribution of the data.

Step 2. The median value of each division of data described one category.

Following this step, the parametric and multilevel categorical explanatory variables were in a similar format, that is, in categories. The same approach was then undertaken to determine the most appropriate form in which to apply the variable to the model for headache. All levels within the variable were addressed as independent components of a multiple logistic regression model, in which headache was the outcome (Andersen 1990). One level of the explanatory variable was designated as the comparison level, for which the odds ratio for headache was set equal to One. Odds ratios for each of the remaining levels of the variable were compared with that of the comparison category, and ranked accordingly. Dose-response curves were plotted for divisions in the parametric variables to clearly describe the relationship with headache. Broad modelling arguments were applied to each variable according to the degrees of change in odds ratios between data divisions. The explanatory variables were expressed in dummy forms, in which the division(s) with high risk of headache took the value of 1, and the division(s) with low risk of headache took the value of 0.

¹². Dividing the parametric data into five equal parts for the purpose of causal modelling was discussed in Chapter Two.

3.7.5 The estimation of effect between headache and its predictors

3.7.5.1 Univariate estimation of effect

Crude odds ratios, derived from the exponentiated parameter estimates from univariate logistic regression models, estimated the strength of the association between headache and its putative causes. The 95% confidence limits were derived from the parameter estimates and their standard errors.

3.7.4.2 Multivariate estimation of effect¹³

Confounding

The unadjusted association between headache and cervical excursion angles (expressed as crude odds ratios) was adjusted by each potential confounder, and a difference of 10 per cent or more between the crude and adjusted odds ratios was employed to detect confounding (Greenland 1989).

Modification

Effect modification was discussed in this study only under a multiplicative model. There was no biological theory to support either the additive or the multiplicative model as the most appropriate one for the relationship between headache and cervical posture. The multiplicative model was adopted because of the widely held belief amongst biomechanists and anatomists that the relationships between cervical biomechanics, posture and headache were complex and inter-twined, and that change in the performance of one component of the cervical spine directly influenced the behaviour of all other aspects of the cervical spine (Gurumoorthy 1991, Janda 1988, Twomey and Taylor 1984, Schonstrom et al 1993). The multiplicative model allowed such complexities to be taken into account.

¹³. The conditions under which other causes of headache influenced the association between posture and headache were established in Chapter Two.

Modification of the association between excursion angles and headache was evaluated by comparing the odds ratios in four strata:

1. (0,0) (where dummy variables for both cervical excursion and the other cause took the value 0);
2. (0,1) (where the dummy variable for the other cause took the value 1, and the dummy variable for cervical excursion took the value 0);
3. (1,0) (where the dummy variable for the other cause took the value 0, and the dummy variable for cervical excursion took the value 1);
4. (1,1) (where the dummy variables for both the other cause and cervical excursion took the value 1).

Positive interaction under the multiplicative model was identified when the product of the (0, 1) and (1,0) cells was considerably greater than the value of the (1,1) cell. Negative interaction under the multiplicative model was identified when the product of the (0, 1) and (1,0) cells was considerably less than the value of the (1,1) cell. There was considered to be no modification effect where the product of the (0, 1) and (1,0) cells approximated the value of the (1,1) cell.

3.7.5.3 A diagnostic test for headache

Relevant components were identified for a predictive model for headache, in which the primary exposure term was a dummy predictor for cervical excursion angles. The linear predictor from this model was expressed as a discriminant function whereby individuals with a score higher than a pre-set threshold were considered to be at-risk of headache. The sensitivity and specificity of the model were reported (Hills 1966). The performance of the model was tested on the independent sample of subjects described as Set C in Figure 3.1.

Key Points

This chapter described the study method.

- An observational study was employed to measure the prevalence of headache associated with cervical factors. Time and cost constraints limited the study design to a cross-sectional one. The prevalence study incorporated an investigation of the reproducibility of measurements of headache and its proposed causes.
- Potential subjects for the study were selected randomly from the electoral rolls of two adjacent municipalities in Tasmania. Exclusion criteria was applied to these subjects to ensure that they had never sustained an injury to the neck or back, and that they had equal likelihood of Exposure and Disease (that they did not suffer from classic migraine, that they did not suffer from a known degenerative disease, that they were not taking regular NSAID's or analgesics, and that women were not pregnant or breast feeding).
- Headache associated with cervical factors was identified using the diagnostic tool described in Chapter Two. Measurements of headache frequency were taken retrospectively over a month, using a time-based categorical scale, and prospectively over a month, using a daily headache diary.
- The Linear Excursion Measurement Device (LEMD) was developed to measure cervical resting posture in a clinical setting. It quantified the linear excursion of two anatomical points on the cervical spine.
- Other causes of headache were measured by existing methods that were appropriate to a clinical setting. Where none were available, new measures were developed.
- The methods used to analyse the data were described in detail.

Chapter Four

The results of the pilot study

This chapter reports on the results of the pilot study in which the protocol and robustness of the Linear Excursion Measurement Device (LEMD) were tested. The Linear Excursion Measurement Device (LEMD) and its protocol for measurement were described in Chapter Three. Before undertaking the prevalence study, preliminary investigations were conducted into the reproducibility of LEMD measurements and the suitability of the protocol designed for the LEMD. The twenty subjects who constituted Set A in Figure 3A were employed.

The horizontal and vertical (linear) excursion of the two anatomical reference points was measured for each subject, on four consecutive days. This provided four pairs of linear measurements for each subject for each of the two anatomical points. Each pair of linear measurements was expressed as an angle of excursion using the formula:

$$\text{degrees} = \tan^{-1} \frac{\text{vertical distance}}{\text{horizontal distance}}$$

Four measurements of the angular excursion of each of the two anatomical points were therefore available for each subject.

In Section 4.1 the results of testing are reported. In Section 4.2 the findings are discussed.

4.1 Testing

Linear regression and paired *t* - test procedures were used to compare the four (repeated) measurements of the angular excursion of the superior-most tip of the helix, and the four (repeated) measurements of the angular excursion of the spinous process of C₇. The first measurement was the consistent element in each of the paired tests. The pairs comprised:

- first and second angular measurements;
- first and third angular measurements;
- first and fourth angular measurements.

4.1.1 The association between measurements

Linear regression procedures provided evidence of strong associations between all paired tests. The retest scores explained a high percentage of the variation of the initial scores. The results, reported in Table 4.1, illustrate the stability of the characteristic of the excursion measure over consecutive days.

Table 4.1. The level of association between paired tests

	Paired Tests (<i>n</i> =20)		
	1 & 2	1 & 3	1 & 4
	<i>r</i> ²	<i>r</i> ²	<i>r</i> ²
superior-most tip of the helix of the ear	0.83	0.95	0.87
spinous process of C ₇	0.88	0.87	0.90

4.1.2 Population range and mean values

Mean, standard deviation of the initial measurement of excursion angles were:

- for the superior-most tip of the helix of the ear
5.55 (3.20) degrees (range 2 - 16 degrees)
- for the spinous process of C₇
8.13 (4.81) degrees (range = 2 - 18 degrees).

4.1.3 Difference between means

When determining agreement between measurements taken on separate occasions from the same subjects using the same test, Snedecor and Cochran (1967) recommend ranking the mean differences and conducting significance tests on the pair of tests with the highest ranked difference. If this pair was not significantly different, one could be confident that the differences between all other paired means were not significant. The largest difference between means (l.d.m.), the standard errors and the *p values* from paired *t*-tests are reported in Table 4.2. No significant differences were found between the means of the highest ranked pairs, and thus it was assumed that all paired means were not significantly different. This table also reports the shape of the plot described by Altman and Bland (1983) (A/B plot), in which the difference between scores was plotted against the average score. The horizontal plot suggested consistent variation across the range of the scores.

Table 4.2. The level of agreement between means

		Paired Tests (n=20)		
		1 & 2	1 & 3	1 & 4
superior-most tip of helix of ear	I.m.d.			0.40 degrees
	S.E.	0.29	0.45	0.47
	<i>p value</i>			0.14
	A/B plot	horizontal	horizontal	horizontal
spinous process C ₇	I.m.d.	-0.7 degrees		
	S.E.	0.38	0.45	0.37
	<i>p value</i>	0.09		
	A/B plot	horizontal	horizontal	horizontal

4.1.3 The contribution of subject effects

The contribution of random subject effects to the variation between measurements was described using the output of an Analysis of Variance procedure, conducted under a general linear model. Correlation coefficients were high, and consistently low within-subject variation was noted, suggesting that on an individual basis, subject's measurements differed little between the four tests. The results of testing are reported in Table 4.3.

Table 4.3. Random subject effects

		paired tests	ICC _{1,3} (L95% CL)	% contribution within-subject variation to total variation	Coefficient of Variation (CV)	Root Mean Square Error (RMSE)
helix angle	19df ¹	1 & 2	0.86 (0.82)	4.8%	17.24	0.93
		1 & 3	0.97 (0.94)	1.3%	9.01	0.50
		1 & 4	0.93 (0.85)	3.7%	16.19	0.86
C ₇ angle	19df	1 & 2	0.93 (0.86)	3.7%	14.88	1.26
		1 & 3	0.92 (0.85)	4.0%	16.58	1.40
		1 & 4	0.94 (0.89)	2.8%	13.02	1.08

¹. df is the abbreviation used to denote degrees of freedom.

4.1.4 Protocol

The results of testing suggested that the protocol was appropriate for obtaining excursion measurements at both anatomical points. All subjects understood the verbal instructions and the test procedure was achievable by all subjects. The device performed as anticipated and was sufficiently robust to withstand the rigours of testing. The lack of systematic effects in measurements over the four days suggested that the verbal instructions produced a stable measurement at the first attempt, and that a learning effect had not occurred over the testing period.

4.2 Discussion

The Linear Excursion Measurement Device was designed for a clinical setting to measure the horizontal and vertical excursion traced by anatomical points on the upper and lower aspects of the cervical spine. The device proved to be time efficient, taking a maximum of five minutes to measure each individual and to record the results. The results were immediately available. This was a distinct advantage in a clinical setting when considering the time delay involved in measuring posture by radiographic or photographic measures. The device cost less than A\$200 to manufacture. The protocol was readily understood by all subjects and the device performed robustly over 80 tests. There was evidence for the hypotheses that

- *there was good agreement between measurements taken on four consecutive days of cervical excursion angles; and*
- *the measure of cervical excursion was stable.*

However, despite evidence for the hypotheses, this study was of a preliminary nature only. Only a small number of subjects were involved in the study, and further testing of the reproducibility of the measures was required on a larger group of subjects. Such testing was undertaken and the results are reported in the next chapter.

Key Points

- The Linear Excursion Measurement Device (LEMD) was robust, in that it withstood the rigours of continued use.
- The protocol for using the LEMD was achievable by all subjects in the pilot study, and appeared to not to involve a learning effect over time.
- The LEMD provided measures that had stable characteristics on the first attempt.
- Measurements of excursion at each anatomical point were in good agreement over consecutive days.
- On these findings, I had confidence in employing the LEMD to measure cervical excursion in the prevalence (main) study.

Chapter Five

The results of the reproducibility study

Subjects in Subset B1¹ provided two sets of measurements that were taken one month apart. The comparisons that were made between these measurements are reported in this chapter.

Section 5.1 reports on factors pertaining to headache, including the consistency with which headache was reported and the stability of the headache characteristic. The reproducibility of measurements of cervical excursion is reported in Section 5.2. Factors pertaining to the reproducibility of measurements of the anthropometric and functional variables are reported in Sections 5.3 and 5.4. The reproducibility of the measurement of emotional wellbeing is reported in Section 5.5. Section 5.6 presents a summary of the results.

¹. Subset B1 comprised 93 of the subjects in the main study sample. It was illustrated in Figure 3A.

5.1 Headache: the outcome variable

5.1.1 The consistency of reporting at least one headache

Fifty-eight per cent of subjects reported that at least one headache, identified by the diagnostic tool, had occurred in the month prior to the initial measurement session. At least one event of headache was prospectively reported by 77.8 per cent of those subjects who reported it retrospectively. Retrospective and prospective headache data are compared in Table 5.1. Good agreement beyond chance in the data was evidenced by the Kappa statistic (0.74 (S.E. 0.07))(Richman et al 1980). The headache characteristic was stable, evidenced by measures of strong association (gamma statistic = 0.96 (S.E. 0.07)) and moderate to good correlation (Pearson's correlation coefficient = 0.74 (S.E. 0.07)). There was a high odds ratio that headache was reported in consecutive months (O.R. 56.7: 95%CL 14.2 - 225.8).

Table 5.1. Comparison between retrospective and prospective headache data

<div>retrospective</div> <div>prospective</div>	Headache	No headache	Prospective Total
	headache	0	42
no headache	12	39	51
Retrospective Total	54	39	93

5.1.2 The consistency of reporting headache frequency

The consistency with which headache frequency was reported over consecutive months was examined by comparing the distribution of the prospective headache data with the range of the relevant category of the headache scale. This is reported in Table 5.2a for men and Table 5.2b for women. The range of the nominal category is clear of shading. The shaded areas represent the prospective reports of headache that fell outside the range of the nominal category. This includes the percentage of the total number of subjects in each nominal headache category, who reported headache events outside the range of the nominal category. There were moderate to good levels of association between retrospective and prospective reports of headache for both men and women, described by gamma statistics of 0.86 (SE 0.13) and 0.91 (SE 0.06) respectively, and Kendall tau-b statistics of 0.80 (SE 0.13) and 0.79 (SE 0.08) respectively. For both men and women, there was perfect agreement between retrospective and prospective reports of headache in the category 'none'.

Gender differences were observed in the consistency with which headache frequency was reported. Compared with the prospective reports of headache, men tended to over-report headache retrospectively, while women tended to under-report headache retrospectively.

Table 5.2a. Comparison of retrospective and prospective headache data for

men

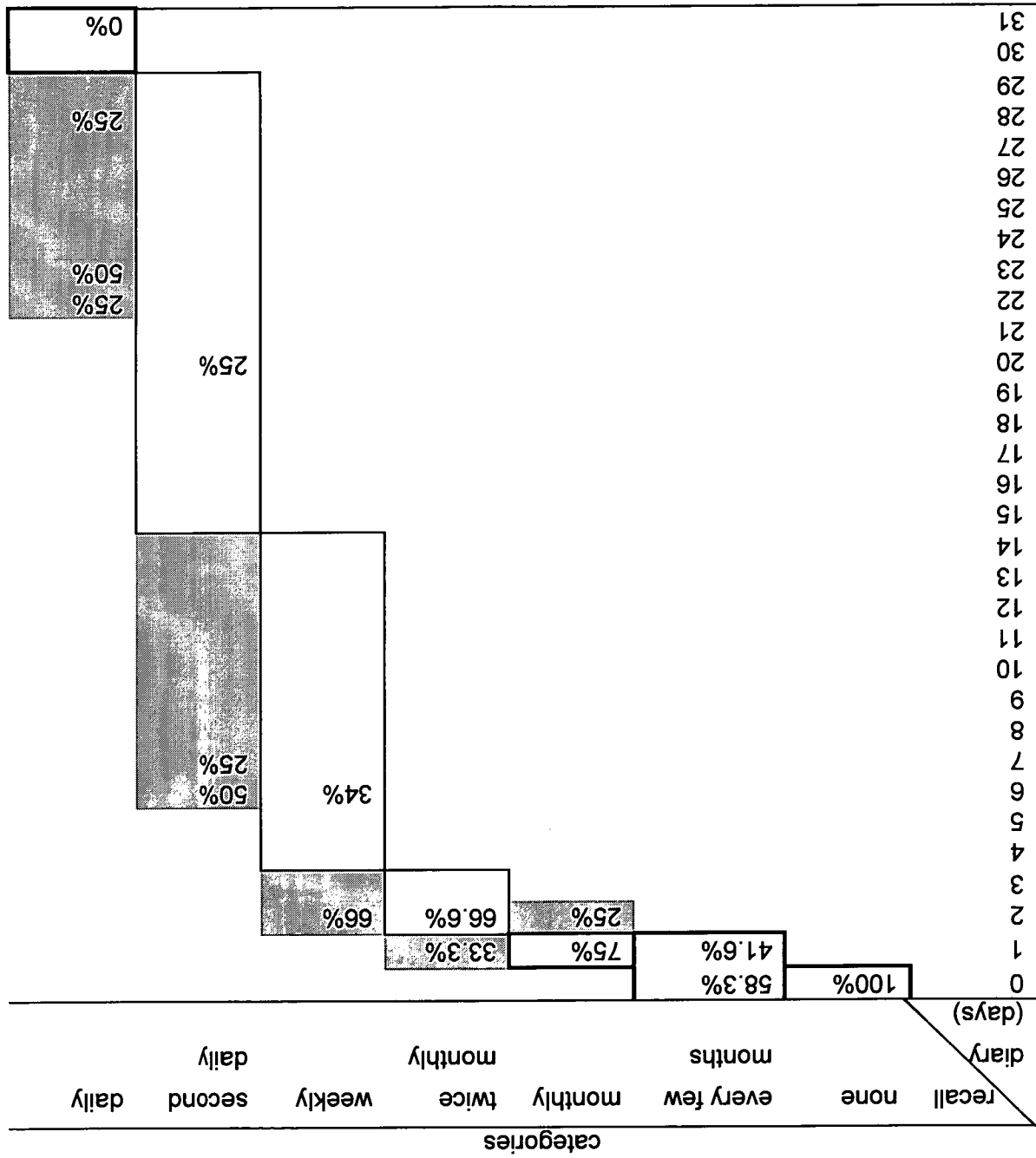


Table 5.2b. Comparison of retrospective and prospective headache data for women

diary (days)	categories						
	recall	none	every few months	monthly	twice monthly	weekly	second daily
0		100%	29%				
1			71%	33.3%	10%	20%	
2				16.7%	70%		
3				33.3%		20%	
4							
5							
6					20%		
7							
8							
9						40%	
10							
11				16.7%			
12							
13							33.3%
14							
15							
16							
17							
18							
19						20%	
20							
21							
22							
23							66.7%
24							
25							
26							
27							
28							50%
29							
30							
31							50%

5.1.3 Occasional and frequent headache categories

The retrospective headache frequency scale provided clear evidence to support the hypothesis that *occasional headache associated with cervical factors was suffered by never-injured subjects*. Headache was reported as occurring less frequently than twice a month. Headache was therefore considered for subsequent analysis in categories of occasional and frequent, where two or more headaches per month was the critical threshold for frequent headache (as reported by Edeling (1988), Jull (1981) and Watson and Trott (1991,1993)), and occasional headache comprised all those headache events occurring less frequently than twice per month.

5.1.4 Misclassification of headache

Potential misclassification of headache was established by comparing prospective and retrospective data in the categories of occasional and frequent headache. This is reported in Table 5.3 for men and women. There was less misclassification of headache by women than men. Occasional headache was prospectively reported by 76.9 per cent of the women and 76.2 per cent of the men who reported it retrospectively. Frequent headache was prospectively reported by 92 per cent of the women and 76.9 per cent of the men who reported it retrospectively. The movement of subjects between headache categories over consecutive months of testing is illustrated in Figure 5.1a for men and Figure 5.1b for women.

Table 5.3. Comparison of retrospective and prospective headache data

<div>prospective</div> <div>retrospective</div>	none	occasional	frequent	Total
		headache	headache	
men				
none	21	3	2	26
occasional	0	16	1	17
frequent	0	2	10	12
Total	21	21	23	55
women				
none	12	1	0	13
occasional	0	10	1	11
frequent	0	2	12	14
Total	12	13	13	38

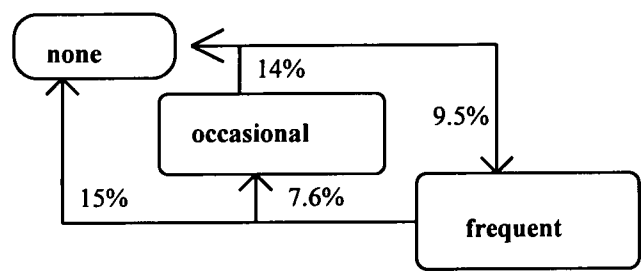


Figure 5.1a. The movement of subjects between headache categories on consecutive months of testing (men)

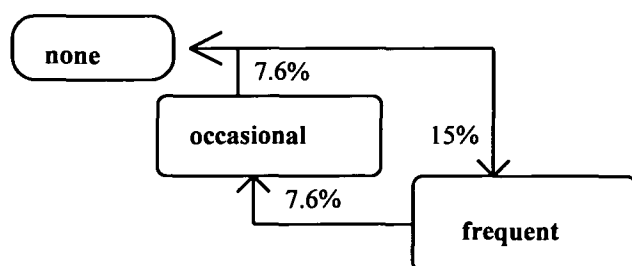


Figure 5.1b. The movement of subjects between headache categories on consecutive months of testing (women)

Overall, headache was misclassified by 8.9 per cent of women and 14.5 per cent of men in Subset B1. However, as the subjects who retrospectively reported suffering headache every few months had a probability of 0.5 of suffering headache in the second month of testing, it may be argued that the occasional headache sufferers were not misclassified; rather their next headache had not occurred within the period of the study. The level of misclassification may have therefore been inflated, particularly as men tended to over-report headache frequency retrospectively. Subset B1 was representative of the main study sample for headache². The stability of the headache characteristic, and the consistency with which subjects in Subset B1 reported headache over consecutive months of testing, suggested that retrospective reports of headache by the main study sample was an appropriate measure of Disease in the prevalence study.

². There were no significant differences between the frequency of headache reported by Subset B1 and the remainder of the main study sample. Test results are reported in Appendix One.

5.1.5 Stiff and aching necks

The consistency of reports of stiff and aching necks by headache sufferers in consecutive months of testing was investigated. For these investigations, headache was treated as the one outcome, regardless of its frequency. The results of testing are reported in Table 5.4.

Table 5.4. Consistency of reporting stiff and aching necks by headache subjects

		gamma statistic	Kappa statistic	Odds ratio
stiff neck	women	0.78 (ASE 0.15)	0.60 (ASE 0.09)	8.00 (95%CL 4.3-24.9)
	men	0.85 (ASE 0.09)	0.61 (ASE 0.10)	12.1 (95%CL 3.1-47.6)
aching neck	women	0.91 (ASE 0.12)	0.64 (ASE 0.13)	30.6 (95%CL 12.7-98.5)
	men	0.81 (ASE 0.12)	0.63 (ASE 0.10)	9.72 (95%CL 2.3-40.4)

The strong correlation between test and retest results supported the conclusion that the measures of stiff necks and aching necks were stable ones. The fair to moderate consistency between these reports suggested that stiff and/ or aching necks were regularly experienced by sufferers of headache specifically associated with cervical factors.

5.2 The reproducibility of the excursion angles over a month interval

Evidence was provided in the preceding chapter of the reproducibility of the excursion angles over four consecutive days of testing. This section provides further evidence that the measurements of excursion over an interval of one month were reproducible, and that there was no systematic influence on the second measurement.

5.2.1 Excursion angles occurring at the spinous process of C₇

The range of the initial measurement of the C₇ excursion angles was 1 - 25 degrees for women, and 1 - 22 degrees for men.

A significant percentage of the variation in the first C₇ measurement was explained by the second measurement (for women, $r^2 = 0.84$ and for men, $r^2 = 0.69$), supporting the stability of the characteristic of angular excursion at the spinous process of C₇. There was moderately high agreement between test and retest measurements, with men being more variable than women on retest, if the initial measurement was in the low excursion angle range. The test effect was non significant ($F < 3.70$, $p > 0.05$) for both men and women ($df = 55,1$ for men and $38,1$ for women). There was no significant difference between test and re-test means for either men or women. The test results are reported in Table 5.5.

Table 5.5. The statistics demonstrating agreement between measurements of C₇ excursion

	mean test 1 (SD)	mean diff (SE)	<i>t</i> -test _(df) (<i>p</i> value)	ICC _{1,3} (L95%CL)	% variation in mean	Altman / Bland plot	CV, RMSE
women	8.74 (4.37)	0.34 (0.28)	1.19 _(38,1) (0.24)	0.91 (0.81)	4.4%	horizontal	14.61 1.25
men	7.89 (4.38)	0.38 (0.34)	1.12 _(55,1) (0.26)	0.83 (0.74)	8.5%	curvilinear in low range	23.19 1.78

5.2.1.3 The time effect on measurement accuracy³

The time effect on measurements of C₇ excursion was investigated by comparing the results of testing over one month with those over consecutive days (the pilot study). Gender effects were not taken into account because there were too few subject numbers in the pilot study (Set A) to adequately assess the gender influence. The results of testing are reported in Table 5.6 and indicated that there was only 3.6 per cent more variation in the mean over a one month interval than over consecutive days.

³. The within-subject variability in measurements taken over consecutive days was reported in the preceding chapter. The comparison of sets of different subjects, drawn randomly from the same source population, was considered to be a valid approach because the ANOVA procedure conducted under a General Linear Model took account of the random subject error.

Table 5.6. The time effect on variability of C₇ excursion

	tests days apart	tests a month apart
highest within subject variation	4.0%	6.8%
Coefficient of variation	16.1	19.7
Root mean square error	1.38	1.59

5.2.2 Excursion angles at the superior-most tip of the helix of the ear

The range of the first measurement of the helix excursion angles was 1 - 18 degrees for women, and 1 - 19 degrees for men.

For both women and men, 80 per cent variation in the initial measurement was explained by the second measurement ($r^2 = 0.80$), supporting the stability of the characteristic of angular excursion at the superior-most tip of the helix of the ear. Women were slightly more variable on retest than men when the initial measurements were in the low excursion angle range. The test effect was non-significant for both men and women ($F < 3.70, p > 0.05$) (df 55,1 for men and 38,1 for women), and there were no significant differences between test and retest means for either men or women. The test results are reported in Table 5.7.

Table 5.7. Comparing helix test and retest measurements

	mean test 1 (SD)	mean diff (SE)	t-test _(df) (<i>p value</i>)	ICC _{1,3} (L95%CL)	% variation in mean	Altman / Bland plot	CV, RMSE
women	4.92 (3.39)	-0.36 (0.05)	-1.15 _(38,1) (0.25)	0.87 (0.74)	6.6%	curvilinear low range	27.33 1.39
men	6.07 (4.05)	0.09 (0.04)	0.34 _(55,1) (0.73)	0.89 (0.83)	5.4%	horizontal	23.09 1.39

5.2.2.3 The time effect

The time effect on measurements of helix excursion was investigated in the same manner as for excursion of the spinous process of C₇. The results of testing are reported in Table 5.8. A time effect was observed, as an additional 10.32 per cent of the mean was accounted for by within subject variability, when one month elapsed between tests.

Table 5.8. The time effect on variability of helix excursion

	tests days apart	tests a month apart
highest within-subject variation	4.8%	5.8%
coefficient of variation	14.33	24.65
root mean square error	0.77	1.39

5.2.3 Conclusion

The measure of angular excursion was stable for men and women at both anatomical points. There was good agreement between measurements taken one month apart. On retest, men were more variable than women when the initial measurement was in the lower end of the C₇ excursion angle range. Conversely, women were more variable than men on retest when the initial measurement was in the lower end of the helix excursion angle range. No systematic changes were observed in the test results for either C₇ or helix. The findings suggested that the Linear Excursion Measurement Device, the subjects, the measurer and the protocol performed similarly on both occasions of testing. I had confidence in employing the measure of angular excursion for the purpose of this study.

5.3 Anthropometric measurements

5.3.1 Precise methods were employed to measure length, height, circumference and weight. The use of a non-stretch tape measure to measure height, circumference and length has been discussed by Amarasinge (1966), while the use of scales to measure weight have been discussed by Tanner et al (1966). An expectation of high reproducibility of height and weight measurements over the month interval was confirmed for both men and women by:

- r^2 statistics of greater than 0.98;
- intraclass correlation coefficients greater than 0.97;
- per cent contribution to the total variation of within-subject variation of less than 1 per cent;
- coefficients of variation and root mean square errors less than 1.

High r^2 values (> 0.98) were also observed for the measurements of circumference and neck length and there were high levels of agreement between the two tests. Horizontal Altman / Bland plots were found in each instance, indicating an even spread in the variability in measurement across the range of the scores. These results confirmed the reproducibility of the measurements of circumference and neck length. The results of testing are reported in Table 5.9.

Table 5.9. Agreement between measurements of anthropometric variables

	mean test 1 (S.D.)	mean diff (S.E)	$t\text{-test}_{(df)} (p \text{ value})$	ICC _{1,3} (L95% CL)	% variation in mean	CV, RMSE
front neck length						
women	15.69 (3.22)	0.03 (0.07)	0.37 _(38,1) (0.71)	0.99(0.98)	0.45%	1.93, 0.30
men	16.60 (1.72)	0.001 (0.02)	0.01 _(55,1) (1.00)	0.99 (0.98)	0.32%	0.81, 0.13
back neck length						
women	11.77 (2.16)	0.13 (0.11)	1.22 _(38,1) (0.23)	0.97 (0.93)	1.7%	1.92, 0.47
men	13.14 (1.50)	-0.04 (0.02)	-1.43 _(55,1) (0.16)	0.99 (0.98)	0.4%	1.02, 0.13
circumference						
women	33.69 (6.39)	-0.08 (0.04)	-1.78 _(38,1) (0.08)	0.99 (0.98)	0.01%	0.59, 0.19
men	39.72 (2.46)	-0.05 (0.03)	-1.76 _(55,1) (0.09)	0.99 (0.98)	0.02%	0.41, 0.16

5.4 Functional measurements

5.4.1 The parametric data

For all the parametric variables, there were high levels of association between data from two occasions of testing. These findings supported the stability of the characteristics of these measures. The amount of the variation in the first test that was explained by the second test is summarised as follows:

mean lateral flexion range of movement:

98 per cent for women, 80 per cent for men;

extension range of movement:

86 per cent for women, 88 per cent for men;

cervical short flexor muscle endurance:

86 per cent for women, 88 per cent for men.

While there was moderate to good levels of agreement between the two sets of scores for all three functional parametric variables, systematic effects were observed on each set of retest measurements. The statistics describing the level of agreement between test and retest measurements are reported in Table 5.10. The systematic changes on each of these variables is discussed separately in the following section.

Table 5.10. The agreement between parametric functional measurements

	mean	mean diff	t-test _(df)	% variation	ICC _{1,3}	CV,	Altman/
	test 1	(SE)	(<i>p value</i>)	in mean	(L95% CL)	RMSE	Bland plo
lateral flexion							
women	36.89 (8.61)	-0.31 (0.25)	-1.24 _(38,1) (0.22)	0.8%	0.98 (0.96)	3.02, 1.12	horiz.
men	39.53 (5.91)	-0.63 (0.36)	-1.75 _(55,1) (0.08)	6.1%	0.88 (0.82)	4.79, 1.91	curvil low & high
extension							
women	49.05 (4.23)	-0.84 (0.75)	-1.12 _(38,1) (0.27)	3.6%	0.93 (0.85)	6.67, 3.27	horiz.
men	56.67 (5.42)	-1.13 (0.58)	-1.93 _(55,1) (0.06)	3.8%	0.92 (0.88)	5.49, 3.11	curvil. lo
cervical short flexor muscle endurance							
women	14.5 (4.3)	-1.16 (0.29)	-4.49 _(38,1) (0.0001)	4.2%	0.92 (0.89)	9.23, 1.35	curvil. low
men	18.2 (3.3)	-0.27 (0.14)	-1.82 _(55,1) (0.07)	3.1%	0.94 (0.90)	4.37, 0.80	horiz.

5.4.1.1 Lateral flexion

Increased variability was observed for men in both the low and the high range of lateral flexion, evidenced by a curvilinear shaped Altman/ Bland plot. Subjects with low lateral flexion and subjects with high lateral flexion improved on retest. The intraclass correlation coefficient was correspondingly lower for men than for women, and a systematic improvement for men on the second test was observed, both as a test effect in the ANOVA procedure ($F=3.07$, $p=0.08$) and as a difference between means ($t=-1.75$, $p=0.08$) ($df = 55,1$ for men, and $38,1$ for women). It was unlikely that measurer error or inappropriate application of the test occurred only for men. It was possible that the results occurred by chance. However, as the protocol for measurement did not allow practice time, it was plausible that some men tried harder on the second test or practised in the interim. Moreover, they may have had a better understanding of the task on the second attempt. However, if the lack of practice time at the first measurement session produced this effect for men, it is difficult to explain why it was not also observed for women. The Altman/ Bland plot for men is illustrated in Figure 5.2.

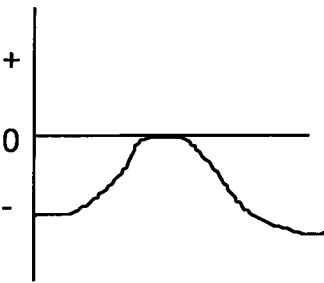


Figure 5.2. An illustration of the Altman/ Bland plot for lateral flexion for men

5.4.1.2 Extension

Good agreement between test and retest scores was noted for men and women. The Altman/ Bland plot was curvilinear for men in the low range of the scores. A systematic improvement was observed on retest for men, both as a significant test effect in the Analysis of Variance ($F=3.80$, $p=0.05$) and as a difference in means ($t=-1.93$, $p=0.06$) ($df = 55,1$ in both instances). This finding indicated that again, only men were influenced by a particular systematic effect. As for lateral flexion, it was plausible that chance played a part. It was also plausible that some men practised in the interim, or that they tried harder on retest to improve their extension range of movement, or that they understood the task better on the second attempt. Given common findings for men for both lateral flexion and extension, the second and/ or third proposals appear likely. However, there is again no ready explanation for the gender differences in the findings. It is implausible that learnt effects in movement are gender-specific.

5.4.1.3 Cervical short flexor endurance

Women had greater within-subject variation than men. The pattern of variation observed in the Altman/ Bland plot suggested that for women, measurements in the middle range of cervical short flexor endurance were in less agreement than those at the low or the high end of the range. The negative differences between scores indicated that women with endurance capacity in the middle of the range generally improved on the second test. This was evidenced by a significant test effect in the Analysis of Variance ($F=19.93_{(df=38,1)}$, $p<0.05$) and the significant t - test statistic (which was reported in Table 5.10).

For men, the plot of the difference between scores against the average of the scores was horizontal, indicating that similar variation occurred across the range of scores. However, a test effect was observed in the Analysis of Variance ($F=3.30_{(df=55,1)}, p=0.07$) as was a significant mean improvement on the second test ($t = -1.83_{(df=55,1)}, p=0.07$). The Altman/ Bland plot for men is illustrated in Figure 5.3.

For both men and women, the characteristic of cervical short flexor muscle endurance was stable, and the pattern of variation in the two sets of scores was similar. The systematic effect on the retest measurements was explained in the following ways. The findings may have occurred by chance. However, the lack of practice time, coupled with the verbal instructions (only) regarding the required manoeuvre, may have produced a learnt effect in the second test. For instance, subjects may have practised in the interim, they may have been more familiar, or tried to do better with the procedure at the second attempt. Furthermore, measurer error may have occurred, as it required dexterity to manipulate the stopwatch and to observe the chin thrust at the same time. A less likely explanation for the systematic change was that the endurance capacity of some subjects improved in the second test.

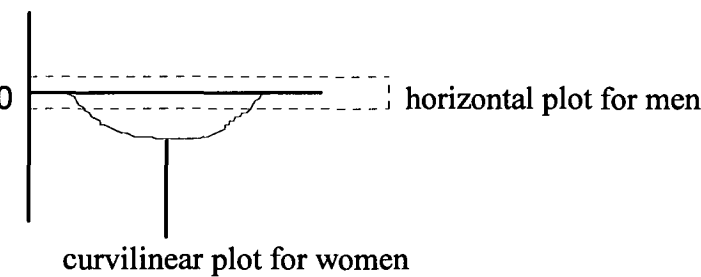


Figure 5.3. The Altman/ Bland plot for cervical short flexor endurance for both men and women

5.4.2 Non-parametric functional variables

5.4.2.1 Cervical flexor strength

Measurements of cervical flexor strength ranged over four of the five nominal categories: less than antigravity strength (2), antigravity strength (3), able to withstand some manual resistance (4) and able to withstand full manual resistance (5) (Janda 1983b). The association between scores suggested moderate to good stability of cervical flexor strength; the gamma statistic was 0.83 (ASE 0.08) for men and 0.79 (ASE 0.10) for women. The level of agreement between the test and retest measurements was moderate (Richman et al 1980), as the Kappa score for men was 0.72 (ASE 0.09), and for women, 0.67 (ASE 0.08). These findings suggested that the reproducibility of the measurements of cervical flexor strength, using the Janda scale, was moderate for the never-injured subjects in this study.

5.4.2.2 Cervical extensor strength

The measurements of this variable ranged over three of the five available nominal categories: antigravity strength (3), able to withstand some manual resistance (4) and able to withstand full manual resistance (5) (Janda 1983b). The level of association suggested moderate to good stability of the characteristic of the measure, where the gamma statistic for men was 0.81 (ASE 0.07), and 0.77 (ASE 0.09) for women. There was a moderate level of agreement between the test and retest scores. The Kappa score for men was 0.71 (ASE 0.08), while for women, it was 0.69 (ASE 0.11). These findings suggested that the reproducibility of measurements of cervical extensor strength, using the Janda scale, was moderate for the never-injured subjects in this study.

The reproducibility of both strength measurements may well have been influenced by the 'no practice' protocol.

5.5 Emotional Wellbeing Schedule

The internal consistency of the Emotional Wellbeing Schedule (Nunnally 1972, Richman et al 1980) was moderate (0.69) for both the test and the retest data (0.65). For interest it was also calculated on the data on 427 subjects, and was also found to be moderate (0.69).

The retest data explained 95 per cent of the variation in the test scores for women and 74 per cent of the variation for men. The characteristic of general wellbeing was stable for both men and women. Horizontal Altman/ Bland plots were observed for both men and women, indicating even variation between test and retest scores across the range of scores. While there was no test effect on the measurement of emotional wellbeing ($F<3.70, p>0.05$) ($df = 55,1$ for men and $38,1$ for women), greater within-subject variation was observed for men than for women. The agreement between scores is reported in Table 511.

Table 5.11. Reproducibility of measurements of General Wellbeing

	mean test 1 (S.D.)	mean diff (S.E)	t-test _(df) (<i>p</i> <i>value</i>)	ICC _{1,3} (L95%CL)	% variation in mean	CV, RMSE
women	63.7 (15.9)	-0.60 (0.56)	-1.07 _(38,1) (0.29)	0.97 (0.90)	1.2%	3.86, 2.47
men	63.4 (18.8)	1.12 (0.43)	0.79 _(55,1) (0.43)	0.86 (0.72)	7.1%	11.65, 7.32

Key Points

Headache

- The headache characteristic was stable.
- Headache was reported by the study sample in a range of frequencies: from every couple of months to daily. This provided the first evidence of the range of frequencies with which headache specifically associated with cervical factors was reported by never-injured individuals.
- There was moderate variation in reports of headache frequency over two months of testing. Retrospectively, women under-reported, while men over-reported, headache.
- Three broad categories were applied to the headache data, these being none, occasional (less than two headaches per month) and frequent (two or more headaches per month).
- More than 76 per cent of men and women reported the same frequency of headache on both occasions of testing. Frequent headache was reported more consistently over two months of testing than was occasional headache.
- On evidence of consistency of headache reporting, and on the assumption that prospective reports of headache were more precise than the retrospective categories, misclassification of headache in the sample data was estimated at 8.9 per cent for women and 14.5 per cent for men. This figure may have been inflated because for subjects who reported occasional headache in the first month and no headache in the second month, sufficient time may not have elapsed for headache to recur.

- As the headaches experienced by the sample of 93 subjects were representative of those experienced by the remainder of the main study sample of 427, it was considered that retrospective headache data supplied by all 427 subjects constituted an appropriate Disease measure for subsequent analysis.

Linear Excursion Measurement

- The excursion of anatomical points on the distal and proximal aspects of the cervical spine, measured by the Linear Excursion Measuring Device, was reproducible over a month interval. The lack of practice, as stipulated in the protocol, did not appear to influence the reproducibility of the initial measurements.

Other study variables

- Measurements of the anthropometric variables were highly reproducible for both men and women.
- Measurements of the functional variables were moderately reproducible. Systematic improvements in scores were observed for cervical short flexor endurance for men and women, and for lateral flexion and extension for men. The 'no-practice' protocol may have influenced the reproducibility of the first measurement in all instances.
- Measurements of emotional wellbeing were moderately reproducible for both men and women.

Chapter Six

Headache: the outcome variable

This chapter examines features of the outcome variable, headache, using data contributed by the subjects in the main study sample. The overall prevalence of headache, and the prevalence of occasional and frequent headache is reported in Section 6.1. Investigations into the differences in functional and emotional characteristics of subjects who reported none, occasional and frequent headache are reported in Section 6.2. In Section 6.3 factors associated with headache morbidity are investigated. The raw data associated with these investigations are provided in Appendix Three.

6.1 The prevalence of headache

6.1.1 Overall prevalence of headache

Prevalence has been defined as 'the proportion of a population that is affected by disease at a given point in time' (Rothman 1986 p. 32). In the study sample, the prevalence of headache specifically associated with cervical factors was high. Of the 427 subjects in the main study, 272 of them (63.7 per cent) reported that at least one headache, consistent with the diagnostic tool, had occurred in the month prior to the measurement session. Headache associated with cervical factors was of a specific nature. Subjects either reported headache matching all three elements of the tool, or none at all. No subject reported only one or two elements of the diagnostic tool. The prevalence odds of headache associated with cervical factors was high (1.75).

Occasional headache was reported by 151 subjects of the 427 subjects, this being 55.5 per cent of the headache sufferers. 121 of the 427 subjects, the remaining 44.5 per cent of the headache sufferers, reported suffering frequent headache in the month prior to the measurement session. Those 155 subjects who did not report headache were classified as non-Diseased.

Four of the 121 subjects who reported frequent headache complained of headache at the time of measurement.

6.1.2 The effect of gender on headache prevalence

6.1.2.1 Gender differences overall

This section reports on the results of testing the hypothesis that *there are gender differences in the prevalence of headache*. The hypothesis was tested by comparing the proportion of men and women with headache and no headache. Evidence was found against the null hypothesis. There was no overlap between the lower 95% confidence limit for the proportion of men with no headache and the proportion of women with no headache. There was also no overlap between the lower 95% confidence limit for the proportion of men with headache and the proportion of women with headache. 44.4 per cent of men (± 6.7 per cent) and 28 per cent of women (± 6.1 per cent) reported that they did not suffer headache consistent with the diagnostic tool, while 55.6 per cent of men and 72 per cent of women reported suffering headache consistent with the tool.

These findings were in accordance with other studies, which reported that women suffer more tension-type and more migraine headaches than men (Dalessio 1986, Lance 1982, Waters 1974). The prevalence odds for headache specifically associated with cervical factors illustrated gender differences in headache occurrence, being 2.57 for women compared with 1.25 for men. Figure 6.1 illustrates the percentage of women with, and without headache (using shaded columns), and these percentages are compared with the percentage of men with and without headache (illustrated as a short line). The confidence limits around the percentage of men with and without headache is provided as an illustration of the gender differences in headache prevalence.

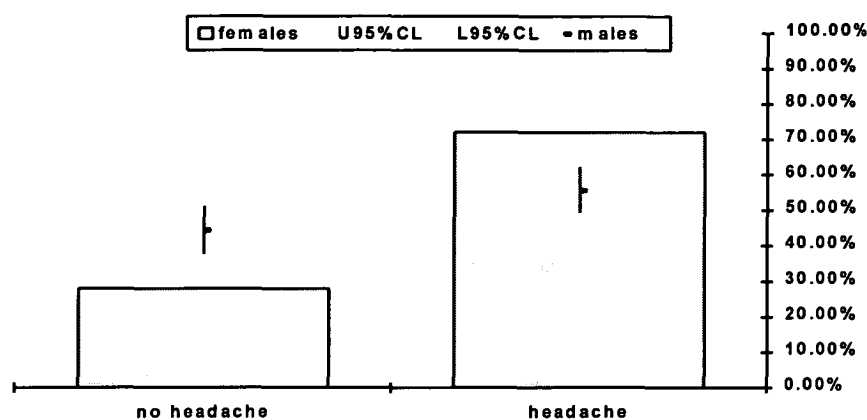


Figure 6.1. The percentage of men and women with headache, compared with those with no headache.

6.1.2.2 Gender differences in categories of headache

The men and women who suffered headache were divided into categories of occasional and frequent headache, and the hypothesis was tested that *there are gender differences in the frequency with which headache is reported*. There was again evidence against the null hypothesis, as significantly higher proportions of women than men suffered headache occasionally or frequently (45 per cent of men (+/- 7.9 per cent) compared with 55 per cent of women with occasional headache), and 42.9 per cent of men (+/- 8.9 per cent), compared with 57.1 per cent of women with frequent headache). The percentage of women with occasional and frequent headache (shaded columns) is compared in Figure 6.2 with the percentage of men with occasional and frequent headache (short lines). The confidence limits surrounding the prevalence of headache for men are reported in order to illustrate the significant gender differences.

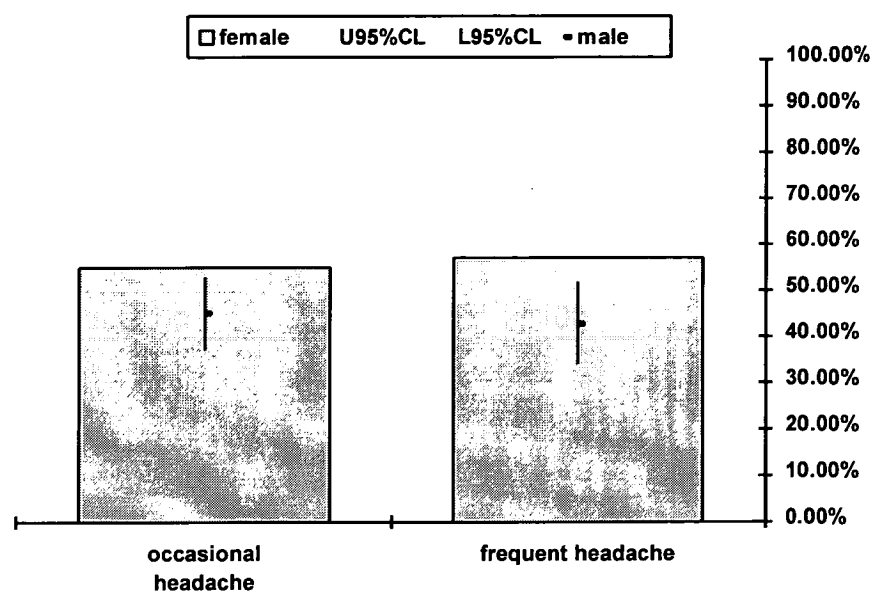


Figure 6.2. The proportion of men and women who reported suffering occasional or frequent headache.

There was an attributable risk for females of occasional headache of 29 per cent, and an attributable risk for females of frequent headache of 35 per cent. The risk estimates are reported in Table 6.1.

Table 6.1. The risk estimates of headache for men and women

		risk rate	risk ratio	% attributable risk to female
occasional	female	58.4 in 100	1.41	29%
headache	male	41.5 in 100		
frequent	female	53.9 in 100	1.54	35%
headache	male	35.1 in 100		

6.1.3 Headache incidence

The data from the prospective headache diaries, recorded by the 93 subjects in Subset B1, provided a basis for examining the incidence of headache^{1,2}. To calculate headache incidence, assumptions were made that all 93 subjects in Subset B1 had experienced their first headache prior to the study, and that each headache event began and ended within a twenty-four hour time period (i.e. one calendar day). The second assumption was supported by studies on chronic daily headache (Sheftell 1992, Silberstein 1992), who considered that each day brought a new headache event.

To calculate incidence, each headache event was given the value of One, and the incidence rate was expressed as the number of headache events occurring within a person-month. Overall, the incidence of headache was 3.25 headache events per person-months. On a gender-specific basis, for men, the incident rate was 2.53 headache events per person - month and for women, it was 4.29 headache events per person - month.

1. The previous chapter reported on the reproducibility study in which 93 subjects supplied prospectively collected headache diaries.

2. Subset B1 was representative of the main study sample for headache frequency.

Evidence of this was provided in Appendix One.

6.2 Functional and emotional characteristics of headache sufferers

This section reports on the results of testing the hypothesis that *the occasional headache is a separate state from no-headache and frequent headache*. Differences in physical and emotional measures were determined for subjects reporting none, occasional or frequent headache. This manner of investigation was directed by studies by Kaganov et al (1981), who identified psychological and physiological differences in sufferers of occasional or frequent tension-type headaches. These researchers proposed the severity model for tension-type headache, in which chronic headaches reflected two interwoven processes: '.....failure to cope with less severe headaches, accompanied by an increasing involvement and automaticity of the underlying psychological and physiological processes' (p. 157). Headache specifically associated with cervical factors has been described by some as a subcategory of tension-type headache. It was therefore plausible that differences existed in emotional and functional characteristics for sufferers of occasional and frequent headache specifically associated with cervical factors.

6.2.1 Testing differences in characteristics of headache sufferers

The study variables³ of emotional wellbeing, cervical short flexor muscle endurance (CSFME), cervical flexor muscle strength (CFS), cervical extensor muscle strength (CES) and extension and mean lateral flexion range of movement were employed to test differences between occasional and frequent headache sufferers and subjects with no headaches.

³. Proposals regarding the nature of the association of the study variables with headache were made in Chapter Two.

Testing was undertaken separately for men and women, and was conducted in two stages: a test of Analysis of Variance was employed to identify overall differences in the selected variables across the three headache categories, and *t*-tests were employed to identify those headache categories between which significant differences occurred.

6.2.1.1 Testing differences overall

Testing using Analysis of Variance procedures identified that for men, mean lateral flexion range of movement was the only variable to differ significantly across the three headache categories. For women, significant differences were identified across the three headache categories in all measures of cervical muscle performance. Means and standard deviations for these variables, and the F values from the relevant ANOVA procedures are reported in Table 6.2a for men and Table 6.2b for women.

Table 6.2a. Functional and emotional measures for men

variable	no headache	occasional	frequent	F value _(df) (<i>p</i> value)
		headache	headache	
	mean (S.D.)	mean (S.D.)	mean (S.D.)	
CSFME (secs)	17.78 (5.07)	18.47 (4.02)	16.94 (5.58)	1.44 ₍₂₎ (0.24)
extension (degrees)	57.71 (8.70)	54.39 (10.76)	56.06 (10.95)	2.22 ₍₂₎ (0.11)
lateral flexion (degrees)	41.61 (6.28)	39.67 (7.60)	38.51 (7.48)	3.65 ₍₂₎ (0.03)
CFS (Janda score)	4.76 (0.54)	4.67 (0.50)	4.67 (0.55)	0.05 ₍₂₎ (0.95)
CES (Janda score)	4.93 (0.26)	4.82 (0.38)	4.88 (0.37)	1.92 ₍₂₎ (0.15)
emotional wellbeing	67.85 (5.86)	67.23 (3.69)	66.92 (4.40)	0.68 ₍₂₎ (0.50)

Table 6.2b. Functional and emotional measures for women

variable	no headache	occasional headache	frequent headache	F value _(df) (<i>p</i> value)
	mean (S.D.)	mean (S.D.)	mean (S.D.)	
CSFME (secs)	15.20 (4.80)	14.82 (5.36)	13.23 (4.55)	2.99 ₍₂₎ (0.05)
extension (degrees)	57.12 (9.52)	56.81 (9.86)	54.89 (9.26)	1.07 ₍₂₎ (0.34)
lateral flexion (degrees)	41.81 (6.22)	41.95 (7.01)	40.43 (6.56)	1.13 ₍₂₎ (0.33)
CFS (Janda scale)	4.22 (0.64)	3.93 (0.71)	3.78 (0.76)	6.17 ₍₂₎ (0.002)
CES (Janda scale)	4.63 (0.49)	4.44 (0.53)	4.29 (0.57)	6.43 ₍₂₎ (0.002)
emotional wellbeing	67.89 (4.40)	66.87 (3.34)	66.52 (5.10)	1.63 ₍₂₎ (0.19)

6.1.2.2 Testing differences between categories

T-tests were employed to compare the measure of mean lateral flexion for men in adjacent categories of headache, and the cervical muscle performance variables for women in the adjacent categories of headache. At the seven per cent level, mean lateral flexion range of movement for men was significantly different between the none and occasional headache categories. For women, the cervical flexor and extensor muscle strength measures (CFS and CES) differed significantly at $p < 0.05$ between the none and occasional headache categories. The cervical short flexor muscle endurance (CSFME) and the cervical extensor strength measures differed between the occasional and frequent headache categories, at the five and eight per cent levels respectively. The results of the *t*-test procedures are reported in Table 6.3a for men and 6.3b for women.

Table 6.3a. The results of *t*-tests between headache categories for men

variable	no headache cf ⁴	occasional headache cf
	occasional headache	frequent headache
	<i>t</i> value _{df = 67,95} (<i>p</i> value)	<i>t</i> value _{df = 67,51} (<i>p</i> value)
lateral flexion	1.78 (0.07)	0.83 (0.41)

Table 6.3b. The results of *t*-tests between headache categories for women

variable	no headache cf	occasional headache cf
	occasional headache	frequent headache
	<i>t</i> value _{df = 82,68} (<i>p</i> value)	<i>t</i> value _{df = 82,58} (<i>p</i> value)
CSFME	0.44 (0.66)	1.95 (0.05)
CFS	2.51 (0.01)	1.21 (0.23)
CES	2.09 (0.04)	1.75 (0.08)

6.2.1.3 The importance of these findings

These findings suggested that in the sample data, occasional headache sufferers differed from those with frequent headache and those with no headache. Occasional headache therefore required investigation as a separate Disease category. These investigations also provided further support for examining gender-specific mechanisms for headache, on the basis of differences between men and women across the three headache categories.

⁴. cf = compared

6.2.2 The frequent headache category

This section presents the results of testing the hypothesis that *the frequent headache category comprises individuals with similar functional and emotional characteristics*. This investigation was undertaken because the frequent headache category comprised widely varying frequencies of headache. It had not been demonstrated that the characteristics of individuals suffering two headaches per month differed from those of daily headache sufferers. This investigation was necessary in allaying concerns regarding potential misclassification of frequent headache, particularly as daily headache has been described as a separate headache category (Sheftell 1992, Silberstein 1992). An Analysis of Variance procedure was employed to examine the same functional and emotional variables as the previous investigation, across the component categories of frequent headache (twice a month, weekly, twice weekly, daily). Evidence was provided for the null hypothesis, as no significant differences were observed for either men or women in these variables. The results of testing are reported in Table 6.4.

Table 6.4. Comparing measures within the frequent headache category

variable	men	women
	F value _(df) (<i>p value</i>)	F value _(df) (<i>p value</i>)
CSFME	0.54 ₍₃₎ (<i>0.66</i>)	0.47 ₍₃₎ (<i>0.70</i>)
extension	0.25 ₍₃₎ (<i>0.86</i>)	1.25 ₍₃₎ (<i>0.29</i>)
mean lateral flexion	0.22 ₍₃₎ (<i>0.88</i>)	1.62 ₍₃₎ (<i>0.19</i>)
CFS	0.26 ₍₃₎ (<i>0.86</i>)	1.31 ₍₃₎ (<i>0.28</i>)
CES	0.23 ₍₃₎ (<i>0.87</i>)	0.77 ₍₃₎ (<i>0.52</i>)
emotional wellbeing	1.68 ₍₃₎ (<i>0.18</i>)	0.94 ₍₃₎ (<i>0.42</i>)

6.3 Headache morbidity

This section describes other characteristics of headache in an attempt to more clearly define the morbidity of headache specifically associated with cervical factors in the never-injured subjects.

6.3.1 The remaining pain criteria of Jull (1981)

Headache subjects reported on the remaining four pain criteria from Jull's (1981) list (Criteria One, Three, Four and Seven) (those not included in the diagnostic tool). These criteria were non-specific to cervical involvement in headache, describing the pain intensity and distribution, history and autonomic symptoms associated with headache. There were no significant gender differences, and no differences between occasional and frequent headache, in the frequency with which headache sufferers reported Criteria One (pain distribution) and Criteria Three (pain quality). Reporting of Criteria Four and Seven was clearly associated with headache frequency. More subjects with frequent headache than occasional headache reported the occurrence of autonomic symptoms (Criterion 4) and a long history of headache (Criterion 7). Autonomic symptoms were described as disturbances in vision, nausea, dizziness, jaw and/ or ear aches. Observations by Kaganov et al (1981), Mathew et al (1982) and Saper (1986) were supported by these findings: regardless of headache aetiology, the more frequently headache occurred, the more often it was associated with autonomic symptoms. The frequency with which the remaining pain criteria of Jull (1981) were reported by headache subjects is reported in Table 6.5.

Table 6.5. Percentage of headache sufferers reporting the remaining four pain criteria (Jull 1981)

		Occasional H/A	Frequent H/A
men	Criterion 1	68 (100%)	52 (100%)
women		83 (100%)	69 (100%)
men	Criterion 3	68 (100%)	52 (100%)
women		83 (100%)	69 (100%)
men	Criterion 4	19 (28%)	45 (86%)
women		31 (37%)	56 (81%)
men	Criterion 7	24 (35%)	52 (100%)
women		37 (45%)	69 (100%)

6.3.2 Stiff and/ or painful necks accompanying headache

Stiff and/ or aching necks are reported to commonly accompany headache specifically associated with cervical factors (Bovim and Sand 1992, Pfaffenrath et al 1987, Sjaastad et al 1983). It was therefore hypothesised *that stiff and/ or aching necks were reported by headache sufferers but not by non-headache sufferers*. Data were collected from all subjects (Diseased and non-Diseased) on events of stiff and/ or aching necks occurring in the previous month. Gender differences in reports of stiff and aching necks across headache categories were observed. The findings are summarised in Figure 6.3a for men and Figure 6.3b for women⁵.

⁵. The odd ratios and 95% confidence limits for headache and stiff and aching necks are reported as a footnote to Figure 6D. (The odds ratio when neither stiff nor aching necks occurred was 1).

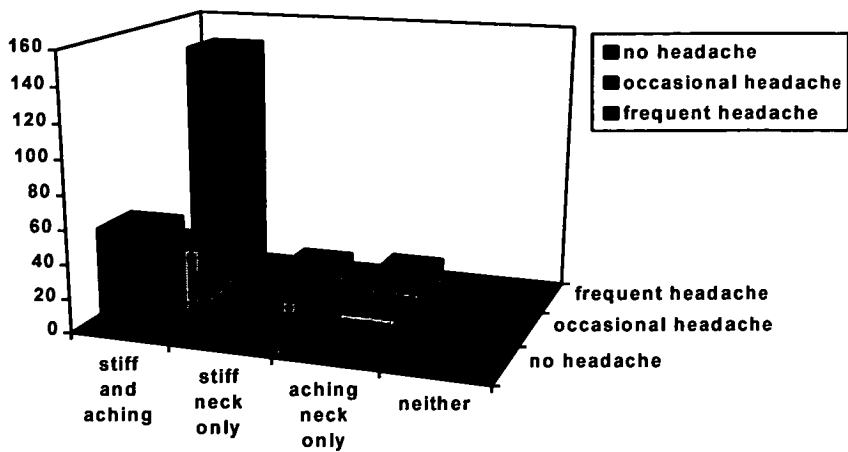


Figure 6.3a. The odds ratios for men suffering stiff and aching necks

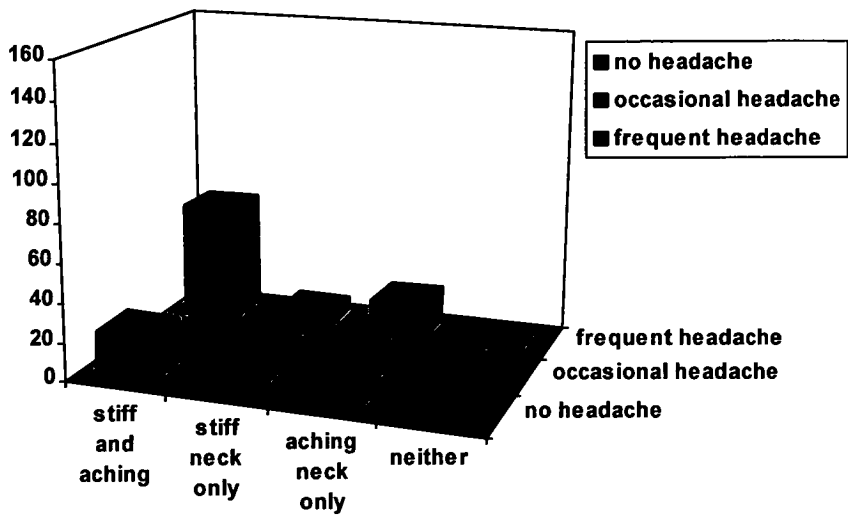


Figure 6.3b. The odds ratios for women suffering stiff and aching necks

		no headache	occasional H/A	frequent H/A
men	stiff neck only	7.78 (1.57-38.5)	7.24 (1.32-39.64)	9.29 (1.25-73.7)
	aching neck only	12.93 (2.36-14.3)	3.97 (1.46-10.80)	11.58 (4.26-31.50)
	both aching and stiff	59.74 (13.33-24.47)	33.11 (8.12-139.77)	144 (29.08-713.37)
women	stiff neck only	12.76 (4.67-34.5)	0.19 (0.03-0.95)	7.31 (0.99-54.06)
	aching neck only	5.81 (1.17-28.8)	0.09 (0.03-0.26)	18.54 (5.58-61.56)
	both aching and stiff	24.05 (7.24-79.84)	0.09 (0.03-0.33)	60.09 (16.61-223.6)

It was noted that reports of stiff and aching necks were not confined to headache sufferers, and therefore an association only between stiff and aching necks and headache could not be supported. However, the highest odds ratios were observed between stiff and aching necks and frequent headache, for both men and women.

Under the multiplicative model, a positive interactive effect on headache was anticipated when both stiff and aching necks occurred together. Concurrent stiff and aching necks were expected to detract significantly from the 'usual' performance of the cervical spine, influencing the neural and vascular supply of 'pain sensitive structures within the neck' (Edmeads 1988, p. 1874).

For men, the anticipated positive interactive effect between stiff and aching necks was observed for both occasional and frequent headache. A similar finding was not observed for women; there was in fact, a mitigating effect when stiff and aching necks occurred together. This finding may have occurred by chance. The observed associations required more rigorous testing, because such major gender differences in the performance of structures of the neck were implausible. While a reduction in cervical movement (as in a stiff neck) may well protect structures that had previously been irritated (as in an aching neck), there was no immediately obvious reason why this should occur only for women.

6.3.3 Headache intensity

A specific measure of the intensity of headache was not recorded in this study because of the issues involved in the validity, definition and interpretation of a measure of intensity in a population-based study⁶.

Nevertheless, because this was the first known population-based study into headache specifically associated with cervical factors, an attempt was made to describe headache intensity, using headache management methods as proxy measures of headache intensity (Edeling 1988, McDowell and Newell 1987, Melzack 1975).

6.3.3.1 Methods of headache management

Common headache management methods were listed in the questionnaire⁷. Headache subjects identified the method that they usually employed to relieve headache. For the purpose of analysis, the methods of headache management were grouped into categories. There were no previous studies to guide such grouping, or ranking the resultant categories for the purpose of analysis. The methods of headache management were therefore grouped and ranked on the degree of effort required to obtain them. For example, Group Two was considered to be different from Group Three because it requires definite, planned effort to obtain and use heat and cold sources, or to make an appointment and attend a health professional.

⁶. These issues were reported in Chapter One.

⁷. The choices were developed from clinical experience, and from reports of the management of headache specifically associated with cervical factors (Jull 1981, 1985, Edeling 1982, 1988, Trott 1988). The list of choices constituted Q23. in the questionnaire in Appendix Two.

Medication was divided in two categories: simple and complex analgesia. Simple analgesia was defined as drugs available in Australia without a prescription, while complex analgesia was defined as drugs available only on prescription from a medical practitioner**. This study did not enquire into the usual dosage of medication because of individual and unmeasured differences in tolerance of pain and of medication. The ranked and grouped pain management choices are listed in Table 6.6.

Table 6.6. Headache management methods

Ranking	Questionnaire elements	Rationale for grouping
1	'The pain just goes away by itself'.	No active management
2	'lie down', 'put on a collar', 'have a sleep'	Passive pain management.
3	'use heat', 'cold', 'massage', physiotherapy/ chiropractic etc.'	Active pain management
4	'take tablets' (e.g. Disprin, Panadol)	Simple analgesics
5	'take tablets'(e.g. Codeine derivatives, Panadeine, Digesic).	Complex analgesics

** At the time the data for this study was collected (1991-2), complex analgesics were not sold over the counter in Tasmania . Since then, complex analgesics have become more readily available without prescription. It is reasonable to assume that individuals with headaches may avail themselves of the opportunity to self medicate with complex analgesics without consulting a medical practitioner.

6.3.3.2 Trends in headache management

There were no obvious differences in headache management methods for either occasional or frequent headache, or for men or women. On this basis the data for men and women were aggregated for testing reported in this section. The percentage of occasional and frequent headache sufferers using each headache management method is illustrated in Figure 6.4. Analgesics bought over the counter (that is, without a prescription) were the treatment of choice for both occasional and frequent headache sufferers.

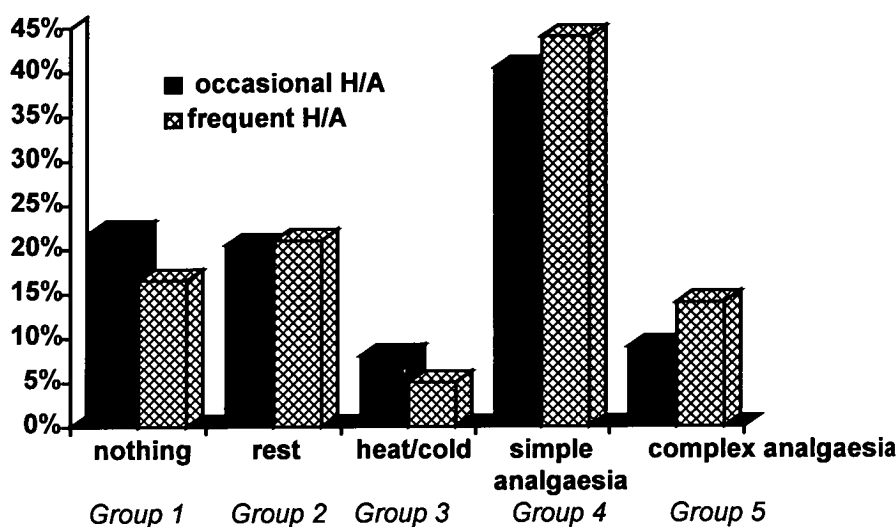


Figure 6.4. The percentage of subjects with occasional and frequent headache reporting each category of headache management

6.3.3.3 Trends in headache management methods used by frequent headache sufferers

The methods of headache management reported by subjects with frequent headache were investigated to test observations by Edeling (1982, 1988) and Pfaffenrath et al (1987) that these individuals use little medication. Over the four categories that constituted frequent headache (twice a month, weekly, twice weekly and daily), no significant trend in the use of analgesia was observed and thus in the sample data these observations were not substantiated. Nevertheless, no subject reporting daily headaches used rest, thermal agents or no management, and in this sense, they differed from all others with frequent headache.

6.3.4 Neck X-ray

X-ray is a diagnostic tool commonly employed by general medical practitioners to diagnose bony injury (Weir 1975). Information on previous neck X-rays was sought to identify subjects who incorrectly answered the pre-enrolment screening question about previous neck injury. This exercise provided assurances that no subject had been incorrectly enrolled into the study. 13.9 per cent of the occasional headache sufferers and 28.1 per cent of the frequent headache sufferers reported neck pain as the reason for X-ray. There were infrequent referrals for X-rays for headache symptoms.

6.3.5 Functional activities associated with headache

Events of functional activities most commonly associated with the onset of headache were requested from headache sufferers. This information is reported and discussed in Chapter Seven in the section dealing with the biomechanics of the cervical spine.

Key Points

- Frequent headache was reported by 28.3 per cent of the study sample, and occasional headache was reported by 35.4 per cent of it. Evidence was provided for the hypothesis that *there are gender differences in the prevalence of headache*, as significantly more women than men suffered headaches.
- Only four subjects reported having a headache at the time of measurement.
- The prevalence of occasional headache in never-injured, middle aged males was approximately 39 per cent. For frequent headache it was 30 per cent. The incidence of headache for middle aged men was 2.75 headaches per person-month.
- There was evidence for the hypothesis that *the occasional headache is a separate headache state from no-headache and frequent headache*. For men, there was a significant difference in mean lateral flexion range of movement between the none and occasional headache categories. For women, there were significant differences between none and occasional headache categories for cervical flexor and extensor strength, and there was a significant difference between the none and occasional headache state for cervical short flexor endurance. These findings provided early evidence to support gender-specific mechanisms for headache.

- Evidence was provided for the null, when testing the hypothesis that *the frequent headache category comprises individuals with similar functional and emotional characteristics*. There were no significant differences in the selected functional and emotional independent variables over the subcategories that constituted frequent headache.
- Aching and stiff necks were not specific to headache. They were reported by subjects in all three headache categories. When aching and stiff necks occurred together, a positive interactive effect under the multiplicative model was observed for men with frequent headache. Under the same conditions, there was a mitigating effect for women for both occasional and frequent headache. This may be a chance result and requires further testing.
- There were more frequent than occasional headache sufferers whose headaches involved autonomic symptoms. This finding supported previous reports that increasing headache frequency was associated with increasing frequency of occurrence of autonomic symptoms.
- There were no trends in headache management methods to distinguish occasional headache sufferers from frequent headache sufferers. Over-the-counter medication was the headache management method of choice, regardless of the frequency with which headache occurred.

Chapter Seven

Cervical resting posture: the putative cause of headache

This chapter reports on investigations into cervical resting posture, the putative cause of headache. The excursion of two anatomical points, one at the superior-most tip of the helix of the ear and one at the spinous process of C₇ described habitual cervical resting posture. The relationship of cervical resting posture to headache had not previously been described. This lack of information prompted investigation of data from this sample to identify the cervical excursion angles that were associated with headache.

Section 7.1 reports on testing the hypotheses that *no subject had resting posture perfectly aligned with the gravitational line*, and that *individuals with excursion angles occurring at either extreme of the population range had poor habitual cervical resting posture*. Section 7.2 reports on the hypothesis that *subjects with two extremely small, or two extremely large angles of excursion, have poor habitual cervical resting posture*. In Section 7.3, efforts are described to identify the most appropriate exposure term in the proposed model for headache. Section 7.4 describes the results of testing the hypothesis that *subjects with excursion angles at the extremes of range suffer more headaches than subjects with cervical excursion that more closely approximates the population norm*. The functional activities that were reported by headache subjects as precursor to the onset of headache are described and discussed in Section 7.5.

7.1 Describing the nature of the excursion angles

This section reports on testing the hypotheses that *no subject had resting posture perfectly aligned with the gravitational line*, and that *individuals with excursion angles occurring at either extreme of the population range had poor habitual cervical resting posture*.

7.1.1 The frequency distribution of the excursion angles

Men and women were investigated separately because gender-specific differences in habitual cervical resting posture have been observed (Dalton 1989, Fulton 1989). The frequency distribution of the natural form of the data was significantly left skewed for both excursion angles, for both men and women. Statistics describing the frequency distribution of the excursion angle data are provided in Table 7.1a for the superior-most tip of the helix of the ear and Table 7.1b for the spinous process of C₇.

Table 7.1a. Frequency distribution statistics for helix excursion angles

frequency distribution statistics	men	women
range (degrees)	1-18	1-17
skewness	0.64	1.18
kurtosis	-0.001	1.31
Shapiro Wilk statistic	0.89 (<i>p</i> <0.01)	0.94 (<i>p</i> <0.05)
mean (S.D.) (degrees)	5.42 (3.45)	6.08 (3.32)
median (degrees)	5	6
25th percentile (degrees)	3	4
75th percentile (degrees)	7	8

Table 7.1b. Frequency distribution statistics for C₇ excursion angles

frequency distribution statistics	men	women
range (degrees)	1-25	1-25
skewness	0.79	0.88
kurtosis	0.61	0.68
Shapiro Wilk statistic	0.91 (<i>p</i> <0.05)	0.94 (<i>p</i> <0.05)
mean (S.D.) (degrees)	7.70 (4.52)	8.45 (4.72)
median (degrees)	7	7.5
25th percentile (degrees)	5	5
75th percentile (degrees)	11	11

There was evidence for the hypothesis that *no subject had resting posture perfectly aligned with the gravitational line*. Evidence would have been found had the excursion angle range begun at zero (this indicating no angular movement away from the vertical (corrected) starting position).

7.1.2 Extreme excursion angles

Subjects with extreme excursion angles were identified by apportioning the data into five divisions of relatively equal size and identifying the first and last divisions as 'extreme' (Cramer 1991, Rothman 1986)¹. This method was chosen over the alternative approach (that of transforming abnormally distributed data to approximate the Normal distribution and then identifying extreme data using standard deviations from the mean) because transforming data diminishes its clinical usefulness (Rothman 1986).

¹. Reasons for treating the data in this manner were provided in Chapter Two.

Moreover, there was no biological theory to guide investigation of the relationship between headache and posture. Rothman (1986) suggests that 'unless positive evidence that the curve implicit in the model is appropriate', categories of the exposure variable should be developed for causal modelling purposes (p. 300).

The excursion angle data at each anatomical point were divided at the same points for men and women because the frequency distributions were similar. The nature of the excursion angle data meant that it could not be divided exactly at 20 per cent intervals. Divisions were therefore made as close as possible to these points. The points of division in the data are reported in Table 7.2, where the median point within each division is reported for future reference.

Table 7.2. Division of the C₇ and helix excursion angle data into five parts

Data division	C ₇ angles	cum. %	<i>n</i>	median point	helix angles	cum. %	<i>n</i>	median point
1.	1 - 4	22.7	97	2.5	1 - 2.5	17.3	74	1.25
2.	4.1 - 6	42.4	84	5	2.6 - 4.0	40.3	98	3.2
3.	6.1 - 8	59.7	74	7	4.1 - 5.9	54.4	67	4.75
4.	8.1 - 11.4	78.2	79	9.7	6 - 8.4	80.3	109	6.4
5.	11.5 - 25	100	93	18.7	8.5 - 18	100	79	13.2

7.2 Resting head posture

This section reports on testing the hypothesis that *subjects with two extremely small, or two extremely large angles of excursion, have poor habitual cervical resting posture*. Investigation was confined to those subjects with similar angular excursion of the upper and lower cervical spine, that is, those subjects with both excursion angles falling in the one data division. It was believed that examination of this subset of subjects would provide clearer descriptions of resting head postures and associated cervical lordoses through the excursion angle range, than would examination of the entire study sample. This specific focus was taken because little is known regarding the manner in which posture develops, and why an individual assumes a particular resting head position. An illustration of the strata in the excursion angle data under examination in this section of the chapter is provided in Figure 7.1.

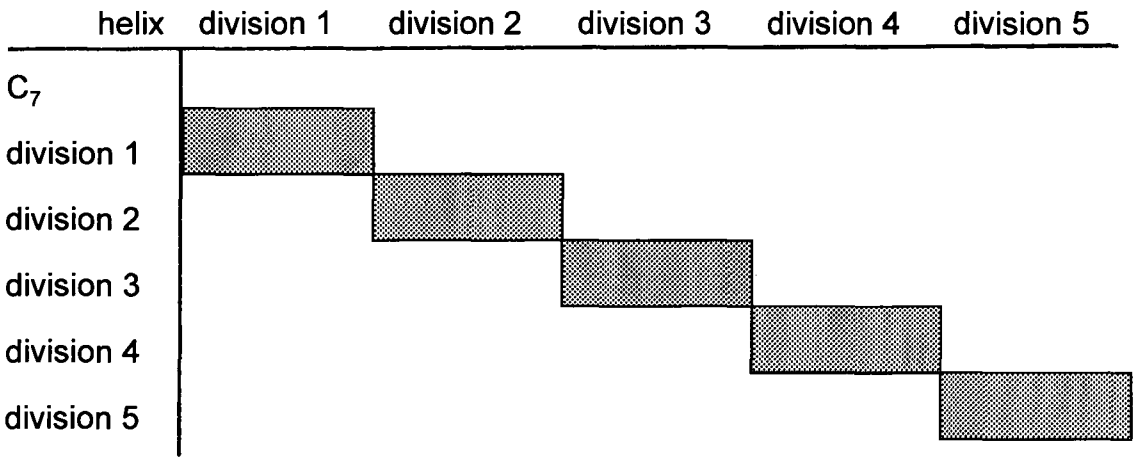


Figure 7.1. The strata in the excursion angle data examined in this section

The decision to examine postures associated with just these strata was justified in the following manner: When comparing the 'ideal' (most efficient) resting head posture (described in Chapter 1, Figure 1B) with the vertical reference line (the backboard) used in the Linear Excursion Measurement Device, the upper and lower aspects of the cervical spine are similarly positioned. However, Penning (1978) reported wide variability in resting head postures of subjects who had not sustained an injury to the cervical spine. Differences in the habitual resting position of the upper and lower aspects of the cervical spine may well occur because of the influence on anti-gravity postural mechanisms, of a large and diverse number of factors (Cailliet 1989, Janda 1988, Penning 1988, Sahrman 1987, Stainsbury and Gibson 1954).. Some of these were identified in Chapter Two as potential causes of headache. Important causal agents of cervical resting posture, their point of effect and nature of action requires more rigorous investigation than it has been afforded to date.

In the absence of such information, for the purpose of this study, large individual differences in the angular excursion of the upper and lower aspect of the cervical spine were proposed as resulting from 'abnormal' causal influences on posture. A proxy control for such influences was exerted by focusing attention on only those subjects with similar amounts of angular excursion at the upper and lower aspects of the cervical spine.

If the angular excursion of both the upper and lower cervical spine was extremely small, or extremely large, subjects were recalled and photographed in their usual resting posture. Photographs were also taken of subjects with both excursion angles falling in the same data division in the more central aspects of the frequency distributions.

The photographs were compared with each other, and with descriptions in the literature of 'Forward Head Posture', to inform a clearer description of 'poor' head posture than is currently available. The master list of identification numbers and contact addresses, compiled by the second scribe during the data collection phase, was used to trace subjects. All the subjects who were contacted, agreed to return for photographs to be taken of them in their habitual resting posture.

7.2.1 Two extremely small excursion angles

Thirteen male and two female subjects had excursion angles that both fell in the first data division. These subjects had a resting head posture where the head was held well forward of the vertical axis, supported by a flexed (protracted) lower cervical spine and a slightly extended upper cervical spine. The cervical lordosis was flat and elongated. This posture is illustrated in Figure 7.2 by a subject with helix excursion of one degree, and C₇ excursion of 2.5 degrees. This posture is similar to that described as 'Forward Head Posture' by Braun (1991), Cailliet (1989), Darnell (1983), Kendall et al (1952), Passero et al (1985), Raine and Twomey (1994) and Stainsbury and Gibson (1954), in which the trunk is slumped forward to support the head and level the eyes.

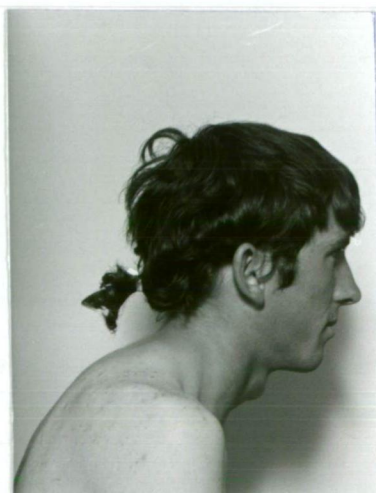


Figure 7.2. Habitual cervical resting posture associated with excursion angles in the first data division

7.2.2 Excursion angles in the central aspects of the data

Excursion angles that fell in the second, third or fourth data divisions described a resting head that was held progressively closer to the vertical axis. Five male subjects and one female subject had excursion angles that both fell in the second data division. Thirteen male and twelve female subjects had excursion angles that both fell in the third data division, and eleven male and eleven female subjects had excursion angles that both fell in the fourth data division. As the excursion angles increased, so did the cervical lordosis. The postures associated with both excursion angles in the second, third or fourth data division are illustrated in Figure 7.3 by subjects with, respectively, helix excursion of 3.5 degrees and C₇ excursion of 5 degrees, helix excursion of 5.1 degrees and C₇ excursion of 7.1 degrees, and helix excursion of 7.5 degrees and C₇ excursion of 9 degrees. The second cervical resting posture in this figure (posture in the third data division) described the population norm, in that it was representative of the central tendency in the both sets of excursion angle data.

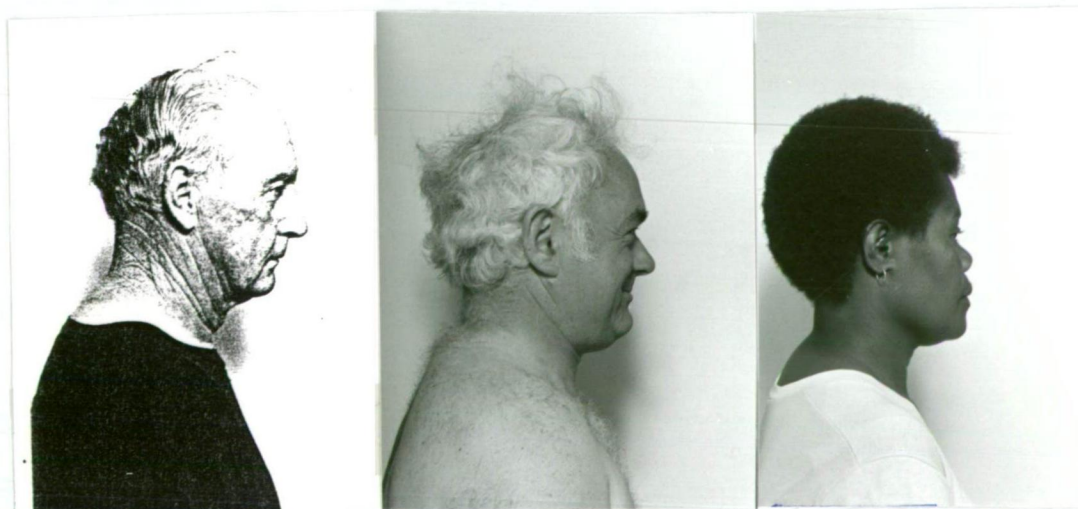


Figure 7.3. Habitual cervical resting posture associated with excursion angles in the second, third or fourth data divisions

7.2.3 Extremely large excursion angles

Fifteen male and fifteen female subjects had excursion angles that both fell in the fifth data division. Their posture was characterised by a leading chin and an occiput that was caudally rotated within the gravitational line. The head was supported on the neck by a markedly curved cervical lordosis. This posture is illustrated in Figure 7.4 by a subject with helix excursion of 14 degrees and C_7 excursion of 19 degrees. This posture is similar to that described as 'Forward Head Posture' by deVries (1966), Hanten et al (1991), Macdonald (1980), and Saunders (1982). This posture implicates C_5 in an increased paradoxical translatory movement on C_6 because of the increased cervical lordosis (White and Panjabi 1990).



Figure 7.4. Habitual cervical resting posture associated excursion angles in the fifth data division

7.2.4 Summary and discussion

Overall, 98 subjects (57 men and 41 women) had excursion angles that were both in the same data division. This represented less than one quarter of the study sample (21.9 per cent) and provided evidence of the wide variability in cervical resting posture in the study sample. Measurement error may have contributed to this finding. There were significant differences overall in the proportion of men and women with both excursion angles in one of the five data divisions ($F=6.57_{(1)}$, $p<0.05$). Differences in proportions of men and women were most noticeable in data divisions one and two.

A comparison of the series of illustrated resting head postures (those associated with both excursion angles in the same data division) suggested that increasing excursion angles were associated with increasing extension of the middle / lower aspects of the cervical spine. The movement of the upper cervical spine was not readily discernible from the photographs. The cervical resting postures associated with extremely small and extremely large excursion angles were similar to those described as 'Forward Head Posture' in the literature, and considered to be 'poor'. Therefore there was evidence for the hypothesis that *subjects with two extremely small, or two extremely large angles of excursion, have poor habitual cervical resting posture*. When the population mean was used as the comparison, extreme cervical resting posture took at least two forms.

This section presents an incomplete picture of 'poor' cervical resting posture, as it examined only those subjects with similar angular excursion of the upper and lower aspects of the cervical spine. Undertaking this manner of investigation was justified by the desire to exert some control on the sample data for 'abnormal' causal influences on postural mechanisms. This approach may well be incorrect and it requires further consideration.

For instance, examination of postures associated with differential cervical excursion angles at the upper and lower aspects of the cervical spine is required, particularly for subjects with one extremely small and one extremely large excursion angle.

The posture defined and illustrated in this study as the population norm also requires further consideration. Its usefulness as a tool for clinical comparative purposes requires field testing. Moreover, before 'poor' cervical resting posture can be fully described with respect to a defined population norm, important causal influences on cervical resting posture require identification and clarification. Such investigations will assist understanding of why individual resting postures are assumed.

There were small numbers of subjects for whom both excursion angles fell in the first and the second data division. This study requires repetition to test whether the observed gender-differences were in fact chance events. However, the difference in proportions of men and women with excursion angles both in the same data division suggest that gender-specific mechanisms may underlie the development of habitual resting head posture. For example, the head posture associated with the first and second data divisions describes a head held well forward of the gravitational line. Men may be more likely to assume this habitual head position because they are believed, on the whole, to have stronger neck muscles and larger neck bulk than women. Gender influences on factors associated with resting head posture require further enquiry.

7.3 The exposure term

The relationship between the C₇ and helix excursion angles was investigated, for the purpose of identifying the most appropriate exposure term to apply to the model to test the association between posture and headache.

7.3.1 Data plots

The helix and C₇ excursion angle data were plotted on a scatter graph. Differently shaped plots were observed for men and women and weak relationships were observed in both cases. The scatter graphs are illustrated in Figure 7.5. These findings did not support the hypothesis that *there are equal and opposite movements of the upper and lower aspects of the cervical spine for all subjects*, and provided early evidence against the development of a single exposure term.

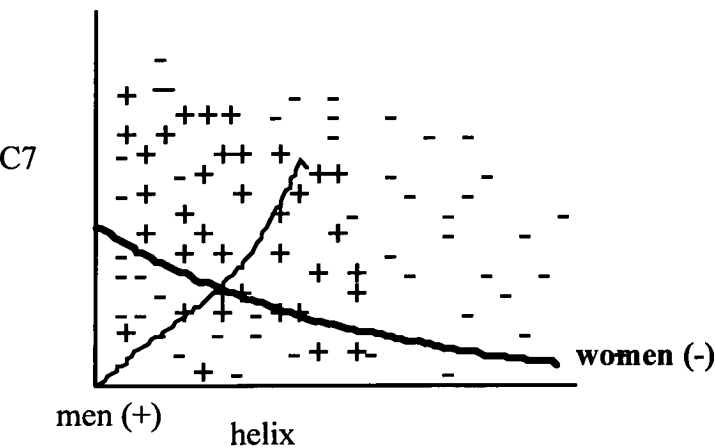


Figure 7.5. Plots describing the gender specific relationship between the excursion angles

7.3.2 The strength of association between the excursion angles

On visual evidence from the scatter plots, a linear regression model was appropriate to the observed relationship between the data. However, a linear regression model requires a normal distribution of the dependent variable. The angular excursion of the spinous process of C₇ was selected as the dependent variable for the model, as an approximation to the normal distribution was obtained by squaring the C₇ excursion angle data for both men and women. Tests of the normalcy of the distribution were provided by Shapiro-Wilk statistics that were not significantly different from One (0.973 ($p=0.06$) for women and 0.978 ($p=0.05$) for men). The linear regression model in which the square of the C₇ variable was the dependent variable was appropriate to the data, as a horizontal plot of the residuals was observed for both men and women.

The linear regression model provided evidence of a weak association between excursion angles in the sample data. 0.28 per cent of the variation in the dependent variable (squared C₇ excursion angles) was explained by the helix excursion angles for women ($F = 0.59_{(1,210)}$, $p>0.05$), while 9.8 per cent was explained for men ($F=23.24_{(1,214)}$, $p<0.05$). It appeared that for both men and women, other factors (such as those identified as causes of headache in Chapter Two) were required as explanatory terms in the model, to more fully describe the nature of the relationship between the excursion angles. The weak association between the excursion angles provided clear evidence of the variability in cervical resting posture in the study sample. The output of the linear regression equations are reported in Table 7.3.

Table 7.3. The linear association between excursion angles

dependent variable (C_7) ²	parameter estimate	Standard Error	<i>p</i> value
men			
intercept	5.50	0.54	0.0001
helix	0.40	0.08	0.0001
women			
intercept	8.72	0.68	0.0001
helix	-0.04	0.09	0.66

7.3.4 Summary

An investigation of the data failed to identify convincing evidence of an association between C_7 and helix excursion angles. In assuming habitual resting head posture, similarly sized movements of the upper and lower aspects of the cervical spine occurred in less than one quarter of the study sample. This study identified the need for clearer insights into the nature of influences on habitual cervical resting posture.

On the basis of the findings reported in this section, attempts to combine the excursion angles into a single explanatory term were abandoned. Separate investigations were undertaken of the association between headache and the excursion angles at the superior-most tip of the helix of the ear, and the spinous process of C_7 . Furthermore, these analyses were undertaken separately for men and women.

7.4 The relationship between the excursion angles and headache

7.4.1 The proportion of subjects with headache

There was no clear evidence of the dose-response relationship between headache and posture for either men or women (Figures 7.6 and 7.7), when examining the proportion of subjects with headache in each division of the excursion angle data. This lack of evidence was highlighted by low measures of association.

For men

- the helix variable, $\gamma = 0.15$ (SE 0.08), Kendall's tau-b = 0.10 (SE 0.06)
- the C_7 variable, $\gamma = 0.07$ (SE 0.09), Kendall's tau-b = 0.05 (SE 0.06)),

For women

- the helix variable, $\gamma = -0.02$ (SE 0.08), Kendall's tau-b = -0.01 (SE 0.06)
- the C_7 variable, $\gamma = 0.13$ (SE 0.07), Kendall's tau-b = 0.09 (SE 0.05)).

However, the high proportion of men and women in the occasional and frequent headache categories who also had extremely large excursion angles (that is, angles in the fifth data division) suggested that for both sexes, extremely large excursion angles were more strongly related to headache than the remaining four excursion angle divisions. Further testing was required in order to develop clearer insights into headache frequency associated with each of the divisions in excursion angles.

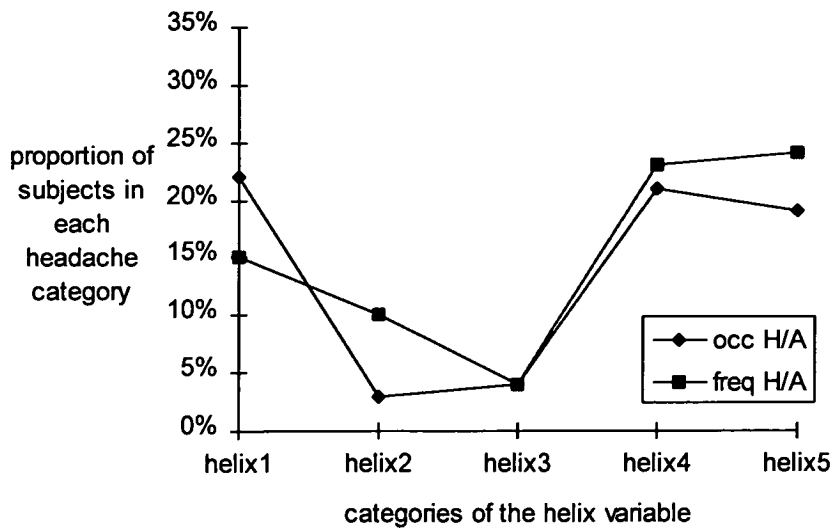


Figure 7.6a. The proportion of men with occasional and frequent headache in each division of helix excursion angle data

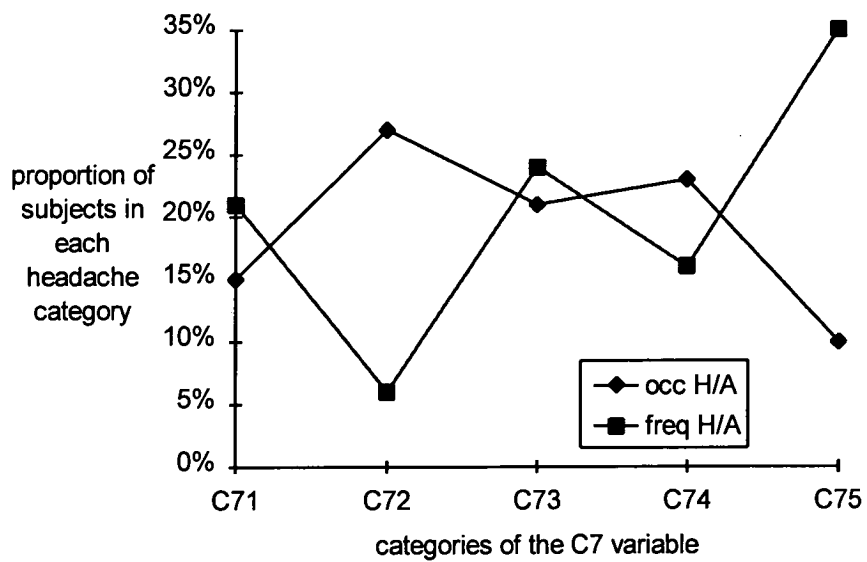


Figure 7.6b. The proportion of men with occasional and frequent headache in each division of C₇ excursion angle data

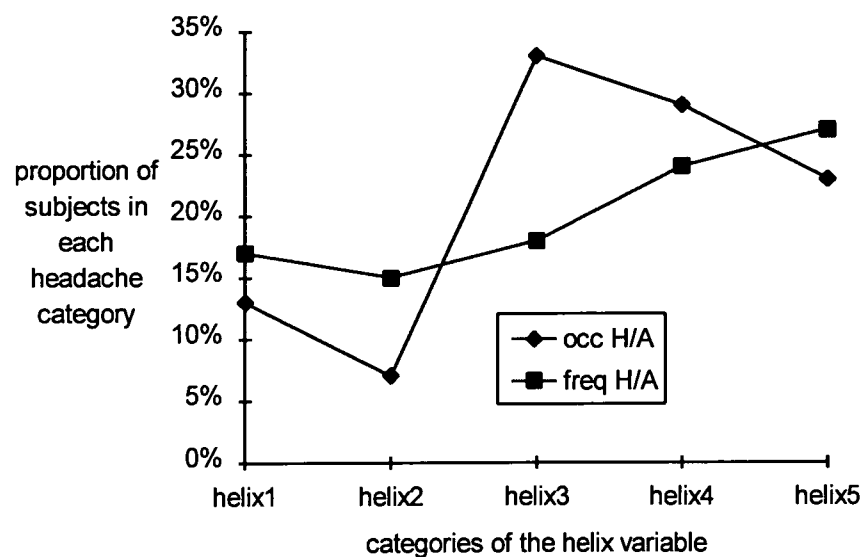


Figure 7.7a The proportion of women with occasional and frequent headache in each division of helix excursion angle data

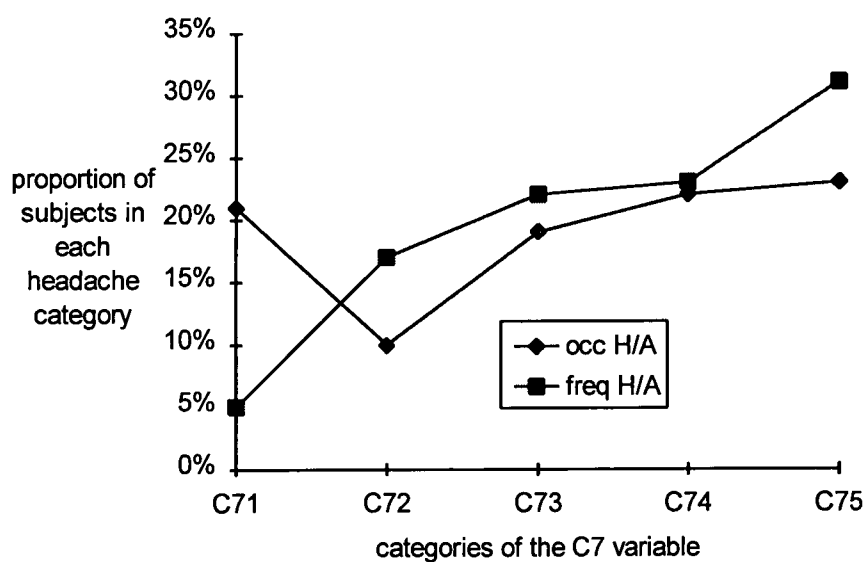


Figure 7.7b. The proportion of women with occasional and frequent headache in each division of C₇ excursion angle data

7.4.2 The odds ratio of headache in each category of exposure

This section reports on further testing to more closely examine the shape of the dose-response curve for excursion angles and headache. The odds ratio of headache in each division of the excursion angle data was calculated as the exponentiated values from the parameter estimates of logit models. The exposure terms were the median values of each division of the excursion angle data (reported in Table 7.2). The logit model is described by the formula $[\log (p / 1-p)]$, where p represented the proportion of subjects with headache.

Testing was first undertaken to confirm that the results of analysis using categories of the excursion angles approximated the results that would be obtained by using the continuous form of the data (Cramer 1991). This was done by comparing the odds ratio for headache (the exponentiated values of the parameter estimate) from the logit model that used the continuous form of the excursion angle data as the exposure term, with the odds ratio for headache (the exponentiated values of the parameter estimate) from the logit model that used the median value of each of the divisions placed in the excursion angle data as exposure terms. Similar results were obtained from both methods of analysis. This confirmed that five divisions in the excursion angle data appropriately represented the continuous form of the data.

The dose-response curves for headache and divisions in the excursion angle data were constructed from the plot of the odds ratios of headache (with associated upper and lower 95% confidence limits), for the second, third, fourth and fifth divisions of excursion angles. These were compared with the first data division, for which the odds ratio of headache was set equal to One.

7.4.2.1 The odds ratios of occasional headache

There was little evidence that a strong association would be found in further testing between either of the excursion angles and occasional headache.

The confidence limits were wide, and in all instances the dose-response curve traced a pattern that was not significantly different to consistent odds ratio of One. The odds ratios of occasional headache with the divisions placed in the excursion angles are plotted for men in Figure 7.8, and for women, in Figure 7.9.

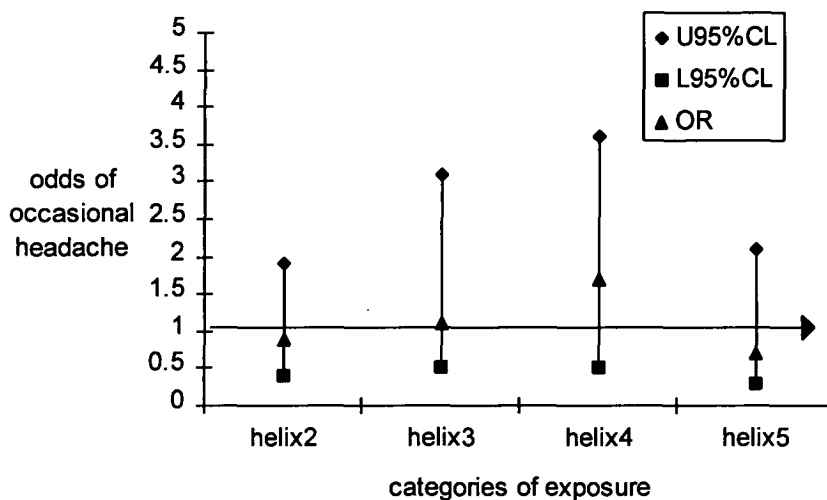


Figure 7.8a. For men, the odds ratios of occasional headache associated with the median value of four divisions of helix excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

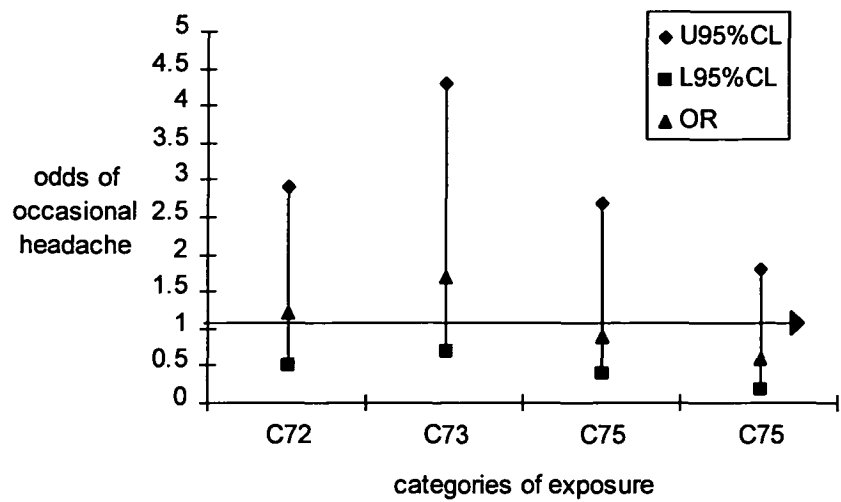


Figure 7.8b. For men, the odds ratio for occasional headache associated with the median value of four divisions of C₇ excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

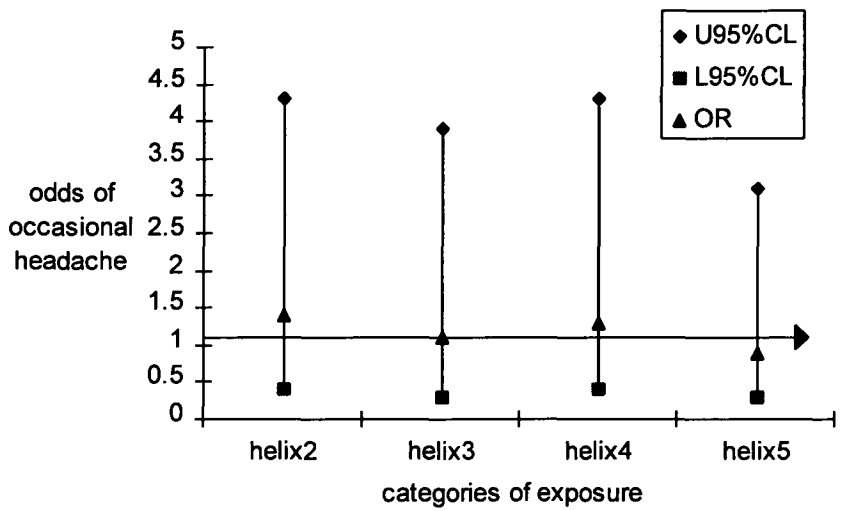


Figure 7.9a. For women, the odds ratio for occasional headache associated with the median value of four divisions of helix excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

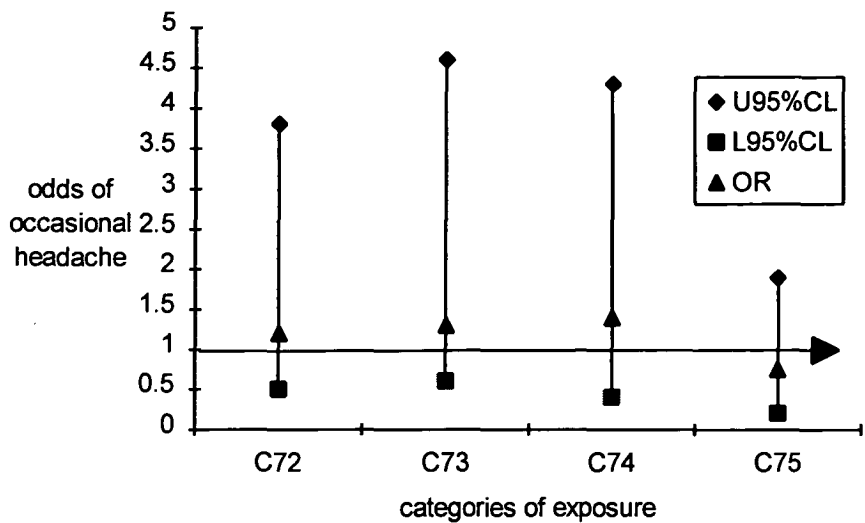


Figure 7.9b. For women, the odds ratios for occasional headache associated with the median value of four divisions of C₇ excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

7.4.2.2 Frequent headache

There was some evidence of an association between the helix excursion angles and frequent headache for men, and between the C₇ excursion angles and frequent headache for men and women. The confidence limits were wide, but the dose-response curve traced a pattern that in each instance appeared to differ from a consistent odds ratio of One. The odds ratios for frequent headache are described for men in Figure 7.10 and for women in Figure 7.11.

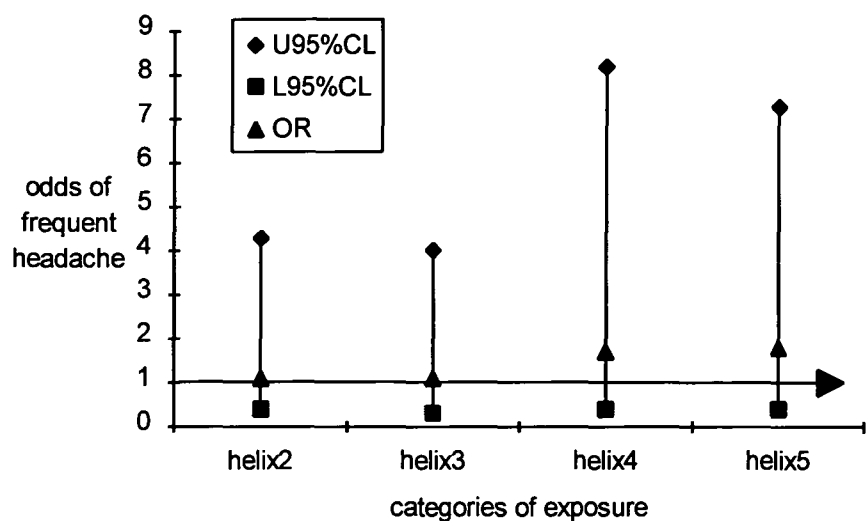


Figure 7.10a. For men, the odds ratios (and 95% CL) for frequent headache associated with the median value of four divisions of helix excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

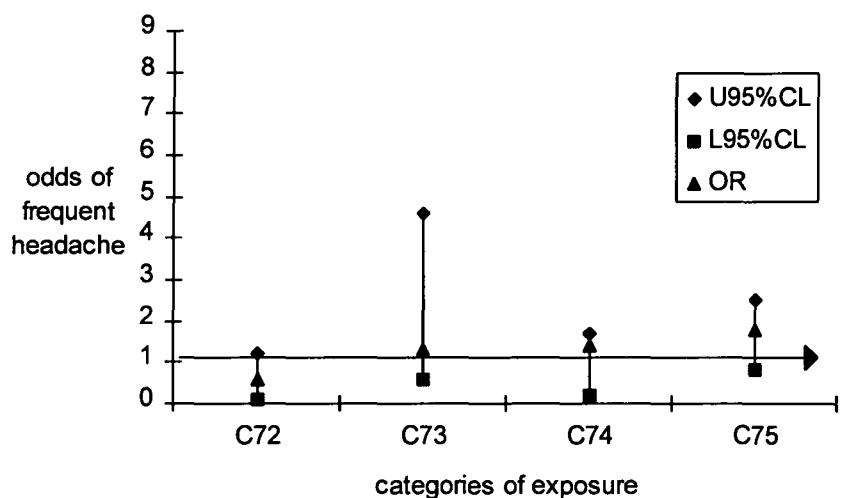


Figure 7.10b. For men, the odds ratio (95% CL) for frequent headache associated with the median value of four divisions of C₇ excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

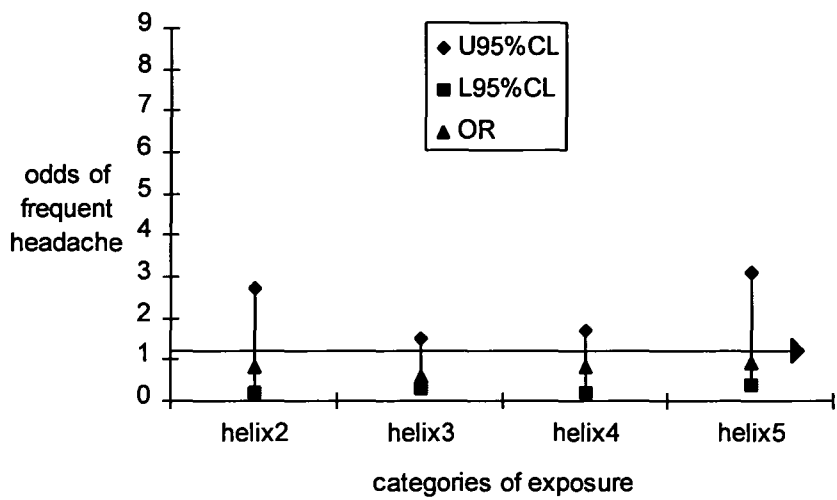


Figure 7.11a. For women, the odds ratio for frequent headache associated with the median value of four divisions of helix excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

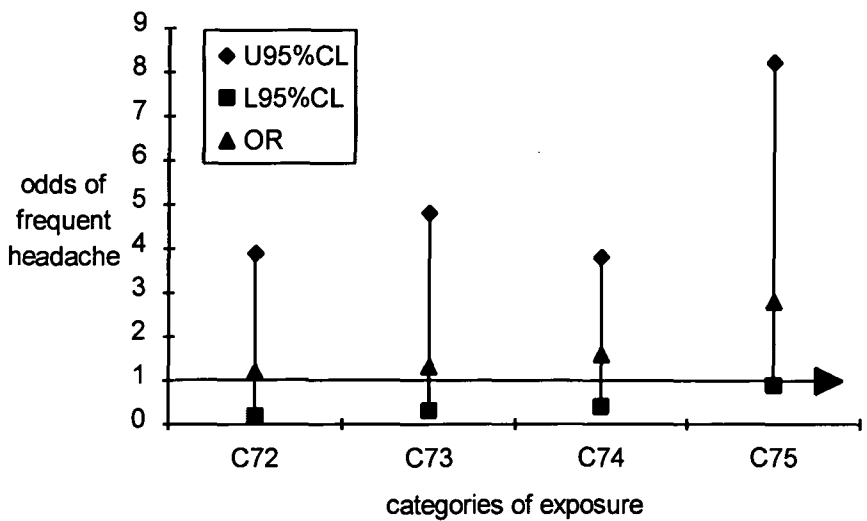


Figure 7.11b. For women, the odds ratios for frequent headache associated with the median value of four divisions of C₇ excursion angles. The odds ratio set equal to One in the first data division is drawn for comparison.

7.4.3 Excursion angle exposure terms

Exposure terms were developed from the excursion angle data on the basis of the dose-response curves for frequent headache. They provided a clearer indication of risk of headache for categories of exposure than the occasional headache curves. For both men and women, the helix angle was dichotomised after the third data division (six degrees). After this point in the data, the odds ratios for headache altered and were subsequently maintained. Helix excursion angles were thus expressed in a dummy form (1 = equal to, or greater than six degrees, 0 = less than six degrees). For both men and women, the C₇ excursion angles were divided after the fourth data division, at 11.5 degrees, this being the point where the odds ratios for headache altered and were subsequently maintained. C₇ excursion angles were thus expressed in a dummy form (1 = equal to, or greater than 11.5 degrees, 0 = less than 11.5 degrees).

These points of division were subjected to further testing using an alternative approach, that of decision tree modelling (Clark and Pregibon 1992). The tree model was fitted to the data using binary recursive partitioning, which splits the data into 'increasingly homogenous subsets until it is infeasible to continue' (Clark and Pregibon 1992, p. 377). This method of testing identified that the odds ratios for headache associated with helix excursion of greater than six degrees and C₇ excursion greater than 11.5 degrees, were similar to the odds ratios for headache at six degrees helix excursion and at 11.5 degrees C₇ excursion. Moreover, it confirmed that the odds ratios for headache at six degrees helix excursion and more than 11.5 degrees C₇ excursion were significantly higher than the odds ratios associated with smaller excursion angles.

7.4.4 The association between excursion angles

The strength of association between the dummy predictors of the excursion angles was stronger for men than women. This was anticipated from previous testing that used continuous forms of these variables. For men, the odds ratio was 4.09 (95%CL 1.99-8.41), while for women, it was 1.21 (95%CL 0.64-2.32).

7.5 Functional activities precursor to headache

Headache sufferers were asked to report the functional activity that commonly preceded headache. This question was asked to:

- investigate the appropriateness of Jull's (1981) sixth criterion to never-injured individuals (i.e. 'Headache is usually associated with sustained neck postures, tension or neck pain and movement'); and
- identify a specific biomechanical action associated with headache.

The reported functional activities were grouped *a priori* according to the gross spinal movement associated with the activity. These were cervical extension, static posture, active cervical flexion, lifting, jarring and stress. Cervical extension activities precursor to headache were most commonly reported by headache subjects overall, and by subjects with excursion angles in the at-risk categories. This finding differed from that of Jull (1986), who reported that static sitting was the posture most associated with headache. Jull's observations were based on self selected headache sufferers, which limited the scope of her findings. However, 60 per cent of occasional, and 46 per cent of frequent headache sufferers, could not identify a particular biomechanical activity that was associated with their headaches. More confidence could have been placed in the reported findings had more headache sufferers provided an answer to this question. The percentage of subjects reporting specific activities precursor to headache is graphed for men and women in Figure 7.12.

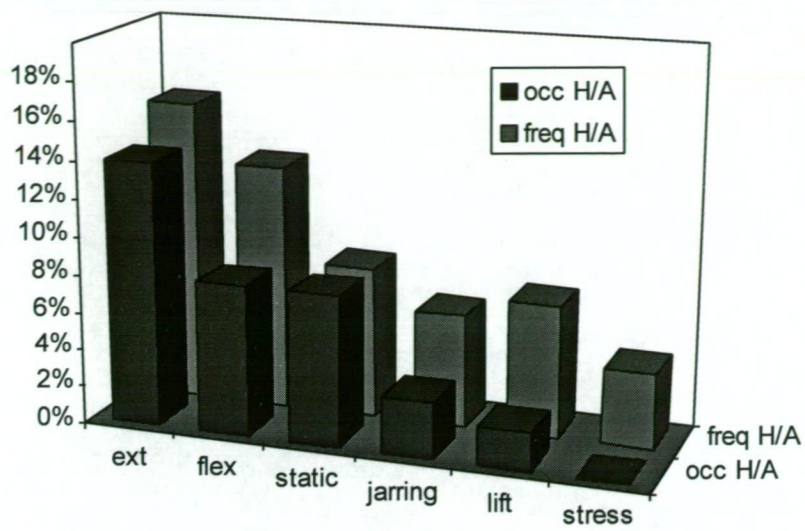


Figure 7.12a². The percentage of male headache sufferers reporting a biomechanical activity precursor to headache.

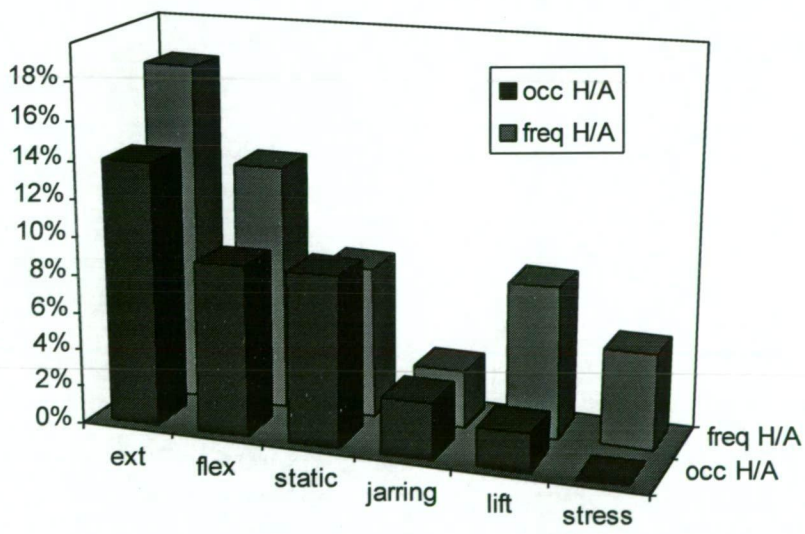


Figure 7.12b. The percentage of female headache sufferers reporting a biomechanical activity precursor to headache.

². The keys used in the graph to denote particular groups of activities are: ext = extension, flex = flexion, stat = static posture, jarring = jarring activities, lift = lifting, stress = stress

Key Findings

- A single exposure term incorporating both C₇ and helix excursion angles could not be constructed. The association between excursion angles was weak for both men and women in the sample data, and it was not possible to describe the relationship of the upper and lower cervical spine during habitual posture in biomechanical terms without more sophisticated methods of measurement.
- There was a clearer dose-response relationship between the helix and C₇ excursion angles and frequent headache, than between occasional headache and the excursion angles. Those subjects with helix excursion angles in the fourth and fifth data divisions, or in the fifth data division for C₇ excursion angles, were more at-risk of frequent headache than subjects in other divisions of the excursion angle data.
- A dummy predictor for helix excursion angles was expressed as helix angles greater than, or equal to six degrees = 1, helix angles less than six degrees = 0. A dummy predictor for C₇ excursion angles was described as C₇ equal to, or greater than, 11.5 degrees = 1, C₇ less than 11.5 degrees = 0.
- The association between the dummy predictors of C₇ and helix excursion angles was stronger for men than women. For men the odds ratio was 4.09 (95%CL 1.99-8.41), while for women, the odds ratio was 1.21 (95%CL 0.64-2.32).
- The cervical resting posture described by subjects with large angles of helix and C₇ excursion, was that where the chin jutted and the head was held close to the gravitational axis by a caudally rotated skull on an extended cervical spine. The biomechanical activity most commonly associated with the onset of headache was gross cervical extension.

Chapter Eight

The association between headache and cervical excursion angles

This chapter reports on the estimation of the strength of association between headache and cervical excursion angles. Section 8.1 reports the crude odds ratios of headache with cervical excursion angles. The association between cervical excursion angles and headache is revised *post hoc*. In Section 8.2 alternative roles for helix excursion angles are proposed and tested. The results are reported separately for men and women.

8.1 The crude odds ratio of headache with cervical excursion angles

8.1.1 The odds ratios of headache with C₇ angles equal to, or greater than, 11.5 degrees and for helix angles equal to, or greater than, 6 degrees were estimated using logistic regression¹. The odds ratio was found as the exponentiated value of the parameter estimate, and the 95% confidence limits were calculated from the parameter estimate and its standard error. The crude odds ratio of occasional headache with the two excursion angles is reported in Table 8.1, and of frequent headache with excursion angles in Table 8.2.

A strong association was observed only between frequent headache and C₇ excursion angles of 11.5 degrees or greater (reported in Table 8.2). On the results of testing:

- the sample data did not provide evidence against the null hypothesis that there was no association between occasional headache and excursion angles for either men or women;
- the sample data did not provide evidence against the null hypothesis that there was no association between frequent headache and helix excursion angles;
- the sample data provided evidence against the null hypothesis involving frequent headache and C₇ excursion angles for both men and women.

Subsequent attention was focused on the association of frequent headache with C₇ excursion angles.

¹. The explanatory variable in one model was a dummy predictor for the helix angle (1 = helix angle of at least 6 degrees, 0 = helix angle less than 6 degrees) and in the other model, it was a dummy predictor for the C₇ excursion angle (1 = C₇ of at least 11.5 degrees, 0 = C₇ angle of less than 11.5 degrees)

Table 8.1. The crude odds ratios of occasional headache with excursion angles²

exposure	O.R. (95% CL) <i>p value</i>	change in -2 log L (<i>p value</i>)
men		
helix	1.07 (0.55 - 2.07)	0.05 (<i>p</i> =0.82)
C ₇	0.50 (0.20 - 1.23)	2.29 (<i>p</i> =0.13)
women		
helix	0.94 (0.47 - 1.85)	0.48 (<i>p</i> =0.78)
C ₇	0.57 (0.23 - 1.37)	1.70 (<i>p</i> =0.19)

Table 8.2. The crude odds ratios of frequent headache with excursion angles³

exposure	O.R. (95% CL) <i>p value</i>	change in -2 log L (<i>p value</i>)
men		
helix	1.73 (0.86 - 3.49)	2.54 (<i>p</i> =0.11)
C ₇	2.29 (1.03 - 5.01)	4.48 (<i>p</i> =0.03)
women		
helix	1.06 (0.52 - 2.14)	0.03 (<i>p</i> =0.86)
C ₇	2.41 (1.00 - 5.81)	4.19 (<i>p</i> =0.04)

². The dependent variable in each regression equation summarised in Table 8A was occasional headache (1 = one or less headaches per month, 0 = no headaches per month).

³. The dependent variable in each regression equation summarised in Table 8B was frequent headache (1 = two or more headaches per month, 0 = no headaches per month).

8.2 The role of helix excursion

This section of the chapter reports attempts to more clearly define the nature of action of helix excursion angles in the association between C₇ excursion angles and frequent headache .

8.2.1 Alternative helix Exposure terms

Subtle effects of association of helix excursion with headache may have been obscured by misclassification of the helix exposure term. The helix excursion angle data were-classified as a trichotomy and the association with headache was further investigated. The five data divisions reported in Chapter Seven were regrouped into three, consisting of the first data division (angles less than 2.6 degrees), the second and third data divisions (angles greater than 2.6 but less than 6 degrees) and the fourth and fifth data divisions (angles of 6 degrees or greater). Compared with helix angles of less than 2.6 degrees, angles greater than six degrees did not confer significantly greater odds of either occasional or frequent headache.

8.2.2 An antecedent or intermediate role of the helix variable

During usual postural manoeuvres, the upper and lower aspects of the cervical spine act inter-dependently; a change in the position of one aspect of the cervical spine effecting a response from the other (Kendall et al 1952, Turner 1956). The individual habitual resting positions of the anatomical points chosen for this study (the superior-most tip of the helix of the ear and the spinous process of C₇) are determined by the manner in which the individual's habitual cervical resting posture develops (Cailliet 1989). No studies have determined whether the development of the position of one aspect of the cervical spine precedes the development of the other, or whether the habitual resting positions of both anatomical points develop simultaneously.

It therefore follows that during usual postural manoeuvres, helix excursion angles are correlates of C₇ excursion angles. Furthermore, in the proposed causal model, helix excursion angles are associated with frequent headache in an antecedent fashion, via C₇ excursion angles.

8.2.2 The confounding and/ or modifying role of helix excursion

A confounding and/ or modifying role of helix excursion angles in the association between headache and C₇ excursion angles was proposed under the particular circumstance:

where habitual resting posture is established, and unusual amounts of helix excursion result from a 'one-off' functional activity.

It was believed on the basis of headache sufferers' reports of the functional activity that commonly precedes headache, that such 'one-off' activities particularly involved sustained neck extension. Examples of these activities include cleaning or painting the ceiling, hanging curtains, and prolonged sitting in a poor position (such as in a theatre). It was proposed that these activities increase usual amount of helix excursion, abnormally stress surrounding cervical tissues, and instigate headache mechanisms. In such circumstances:

- helix excursion angles of greater than six degrees (representative of the position of the upper cervical spine) could be an independent cause of headache (that is, helix angles of greater than six degrees are strongly associated with headache when C₇ excursion angles are less than 11.5 degrees); or
- helix excursion angles of greater than six degrees could act in combination with C₇ excursion angles of greater than 11.5 degrees to increase the odds ratio of headache.

A confounding and/ or modifying effect of helix excursion angles on the association between C₇ excursion angles and frequent headache, was therefore investigated for the purpose of this study, under assumptions that:

- all study subjects were at least 18 years old, and had established adult cervical resting posture (that is, their postural development phase was complete); and
- the excursion at the superior-most tip of the helix of the ear had been recently increased by a 'one-off' functional activity.

Confounding

The confounding effect of helix excursion angles was investigated by adding the dummy predictor for helix excursion angles to a logistic regression model in which the primary exposure term was the dummy predictor for C₇ excursion angles. The results of testing for men and women are reported in Table 8.3. On the basis that a change of 10 per cent or more in the estimated odds ratio indicates confounding (Greenland 1989), a confounding effect of helix excursion on the association between frequent headache and C₇ excursion angles would be identified for men, from an adjusted odds ratio (A.O.R.) of less than 2.07 or greater than 2.51, and for women, from an adjusted odds ratio of less than 2.17 or greater than 2.65.

Adjustment by the helix exposure term altered the odds ratio for men by 12 per cent (A.O.R = 2.01), while adjustment by the helix exposure term did not alter the odds ratio for women at all (A.O.R = 2.41). Under the stated assumptions, there was a confounding effect of helix excursion angles on the association between frequent headache and angular excursion of C₇ of 11.5 degrees or greater for men but not for women.

Table 8.3. The confounding effect of helix excursion on the model

gender	exposure	A.O.R	change in -2 log L (<i>p value</i>)
men	C ₇	2.01 (0.88 - 4.57)	0.92 (0.56)
	helix	1.43 (0.68 - 3.04)	
women	C ₇	2.41 (0.98 - 5.92)	0.01 (<i>p</i> =0.93)
	helix	1.27 (0.77-2.09)	

Effect modification

A modifying effect of helix excursion on the association between C₇ excursion and frequent headache was investigated by calculating the odds ratios for frequent headache in strata of helix angles and C₇ excursion. These are shown in Table 8.4. For women, a high common odds *p value* of 0.94 between the two helix strata, for the association between C₇ excursion angles and frequent headache, indicated homogeneity of effect. For men however, a low common odds *p value* was 0.12 indicated significant differences in effect between strata.

Table 8.4. The stratum odds ratios (upper and lower 95% CL) of frequent headache for C₇ and helix

gender	stratum	C ₇ = 1	C ₇ = 0
men	helix = 1	3.41 (1.03 - 11.54)	1.01 (0.42 - 2.43)
	helix = 0	0.86 (0.42 - 4.01)	1
women	helix = 1	2.50 (0.67 - 9.79)	0.99 (0.45 - 2.22)
	helix = 0	2.34 (0.55 - 10.52)	1

For the helix variable to exert a modifying effect under a multiplicative model, the expected odds ratio of frequent headache (when helix excursion angles of 6 degrees or greater (helix = 1) occurred in the presence of C₇ excursion angles of 11.5 degrees or greater (C₇ = 1)) would be greater than the product of the odds ratio of frequent headache when helix =1 and C₇ was less than 11.5 degrees (C₇ = 0), and when C₇ = 1 and helix was less than 6 degrees (helix = 0). There was no evidence of interaction between C₇ and helix for women, as the expected value of 2.33 was not different from the observed value of 2.50. However, for men, there was evidence of interaction between C₇ and helix, as the expected value of 0.87 was significantly smaller than the observed value of 3.41. The findings are graphed in Figure 8.1.

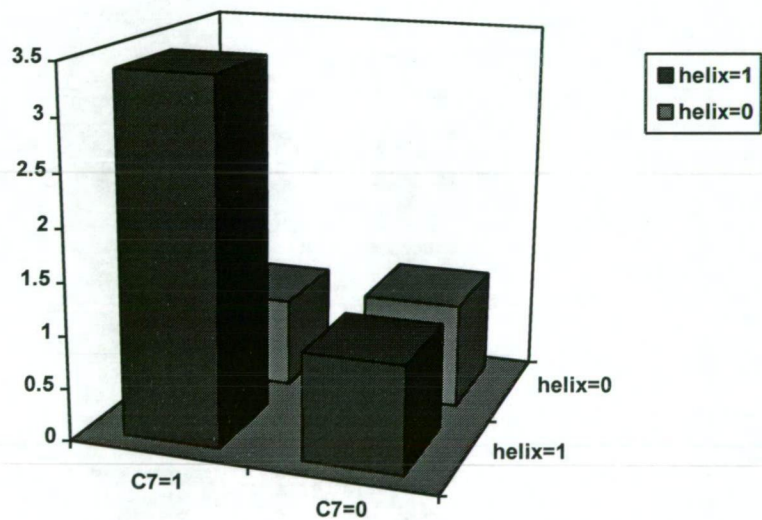


Figure 8.1a. For men: the odds ratios for frequent headache with C₇ excursion angles, modified by helix excursion angles

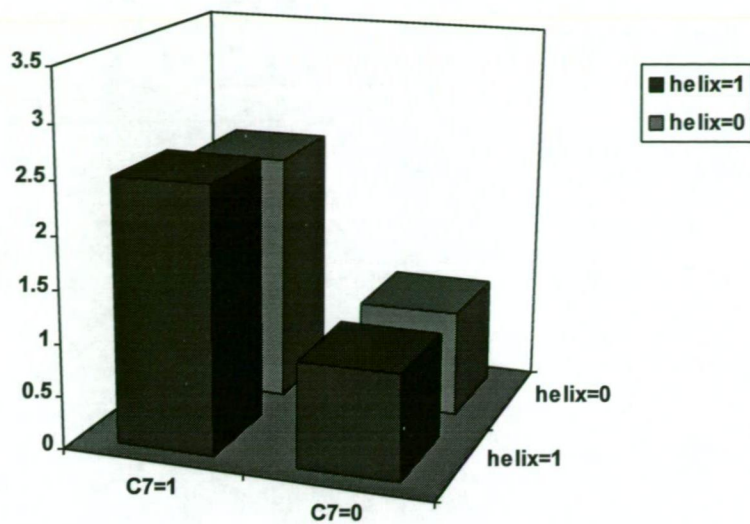


Figure 8.1b. For women: the odds ratios of frequent headache with C_7 excursion angles, modified by helix excursion angles

8.3 Summary

This chapter proposed mechanisms by which the role of helix excursion angles in frequent headache in never-injured individuals could be more clearly defined.

- Helix excursion angles are correlated with C_7 excursion angles under circumstances where posture is developing, or during usual postural manoeuvres. Under these (usual) circumstances, helix excursion angles cause headache only in association with C_7 excursion angles.
- Helix excursion is an independent cause of headache under 'one-off' circumstances, where a particular functional activity unduly influences the amount of helix excursion.

Explanations for the observed gender differences in the action of helix excursion could not be provided by the literature, and none could be interpreted from this cross-sectional dataset. While the differences may be due to chance occurrence, they also may be associated with gender differences in muscle performance or neck bulk. Gender differences in work-related factors are also possible determinants of differential postural relationships.

The following three chapters investigate the role of other causes of headache in the association between headache and the cervical excursion angles. These investigations were undertaken to seek a unifying explanation for the observed gender differences in headache prevalence, and the association between excursion angles and headache.

Key Points

- Occasional headache (headache that occurred less than twice per month) was not associated with helix excursion angles of six degrees or greater, or C₇ excursion angles of 11.5 degrees or greater for either men or women.
- Frequent headache (headache that occurred twice or more per month) was not associated with helix excursion angles of six degrees or greater for women, but there was some evidence of a weak association for men.
- Frequent headache was associated with C₇ excursion angles of 11.5 degrees or greater for both men and women.
- Two mechanisms were proposed for the relationship of helix excursion angles to headache:
 - Helix excursion was a correlate of C₇ excursion during postural development, or during habitual manoeuvres in established posture. It causes headache only in association with C₇ excursion angles.
 - Helix excursion was an independent cause of frequent headache under certain circumstances, that involved 'one-off' functional activities.
- Under the second proposal helix excursion angles confounded and modified the association between frequent headache and C₇ excursion angles for men but not for women.
- A unifying explanation for the gender differences in the association between frequent headache and angular excursion at the superior-most tip of the helix of the ear and the spinous process of C₇ is sought in the following chapters, by examining the influence of other causes of headache.

Chapter Nine

Other causes of headache

This chapter describes investigations to determine the most appropriate form in which to apply other causes of headache¹ to a model for frequent headache². It was believed that investigation of the association of headache with causes, other than cervical resting posture, would provide a unifying explanation for the observed gender differences in the association between frequent headache and excursion angles³. The other proposed causes of headache included continuous and categorical variables. The continuous variables included neck circumference, front and back length of neck, body mass index and cervical short flexor muscle endurance capacity^{2,4}. The categorical variables included brassiere cup size, cervical flexor and extensor strength and occupation². The data were categorised in the same manner as the cervical excursion angles, where the first data division (or the first category) was designated as the comparison category, for which the odds ratio was set equal to One.

1. Other causes of headache were identified and discussed in Chapter Two.

2. The development of minimum modelling assumptions, when there was little biological theory to inform the application of explanatory variables to a model with a categorical outcome variable (headache) was addressed in Sections 2.4.2 and 3.7.5.

3. Gender differences in the association between headache and cervical excursion angles were reported in the previous chapter.

4. Gender differences in explanatory variables were reported in Appendix One.

9.1 The anthropometric variables

9.1.1 Neck circumference

Gender differences were observed in the strength of association of neck circumference with frequent headache. For men, the odds ratios for frequent headache associated with the median value in data divisions two to five, were smaller than the comparison odds ratio of One (set in the first data division). For women however, the odds ratios for frequent headache associated with the median value only in the fourth and fifth divisions of the neck circumference data were smaller than the comparison odds ratio of One (Figures 9.1a and 9.1b). This investigation indicated the need for separate divisions for men and women in the neck circumference data. For men the data were divided at 36 cms, while for women it was divided at 40 cms.

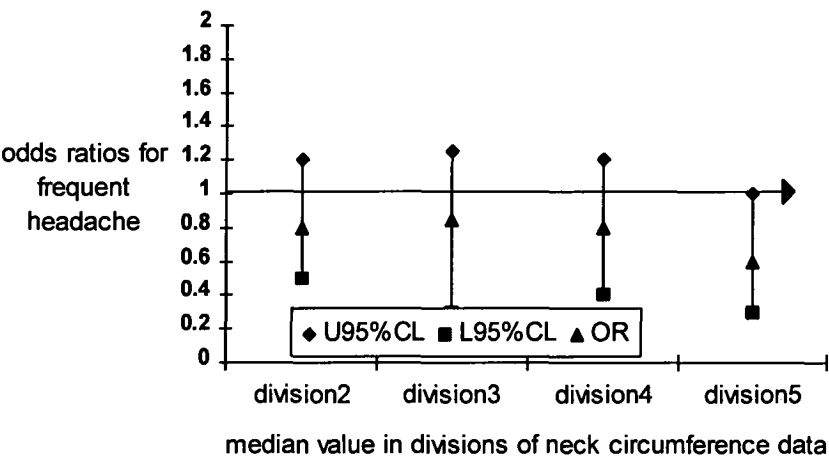


Figure 9.1a. For men: the plot of the odds ratios of frequent headache associated with the median value of the divisions of neck circumference data

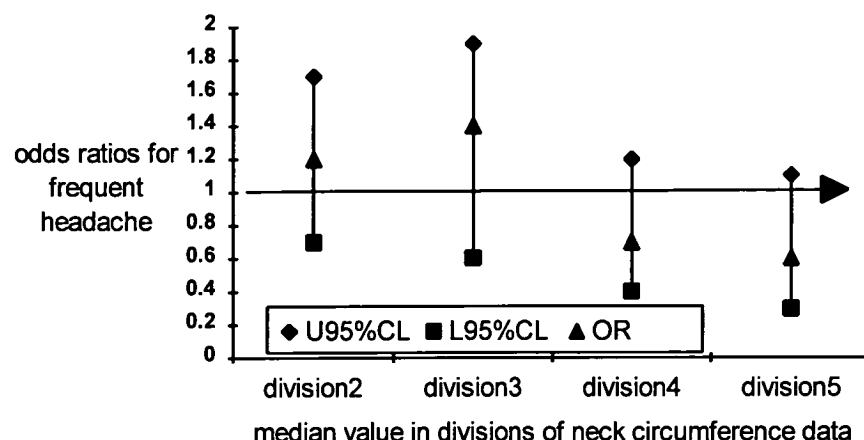


Figure 9.1b. For women: the plot of the odds ratios of frequent headache associated with the median value of the divisions of neck circumference data

9.1.2 The difference between front and back length of neck

No gender differences were observed in the strength of association with frequent headache for the difference between front and back length of neck data. For both men and women, the strength of association with headache increased at the fifth data division. This increase appeared to be significant (Figure 9.2a and 9.2b), because the value of the lower 95% confidence limit approximated One in both instances. This finding suggested appropriate division of the data at four centimetres, for both men and women.

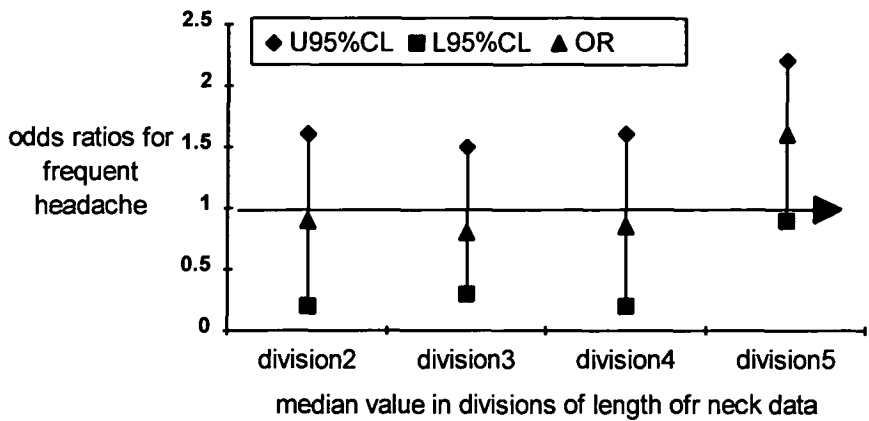


Figure 9.2a. For men: the plot of the odds ratios for frequent headache associated with the median value of the divisions of the data for difference in front and back neck length

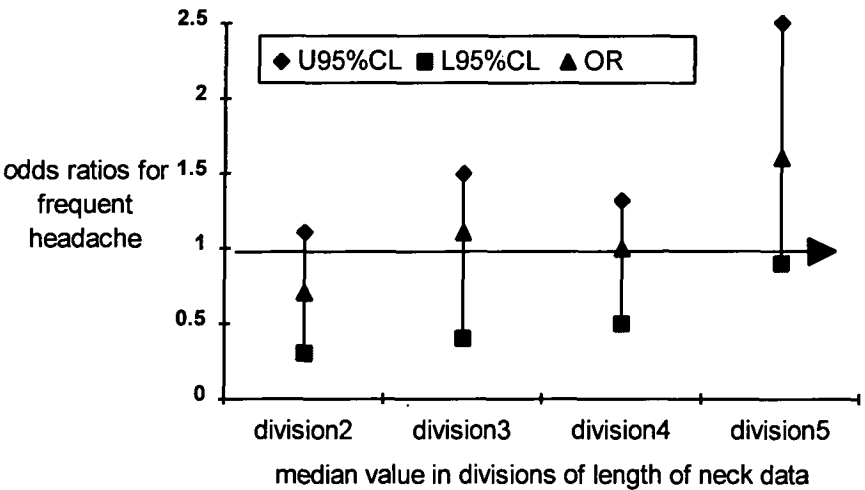


Figure 9.2b. For women: the plot of the odds ratios for frequent headache associated with the median value of the divisions of the data for difference in front and back neck length

9.1.3 Body mass index

There were no observed gender differences for body mass index, in the strength of association with frequent headache. For both men and women, there was a decrease in the estimate of strength of association with frequent headache at the fourth data division. This was maintained in the fifth data division (Figure 9.3a and 9.3b). The approximation of the upper 95% confidence limit to One for the odds ratios in the fourth and fifth divisions supported the significance of the decrease. The data were divided at a body mass index of 24.

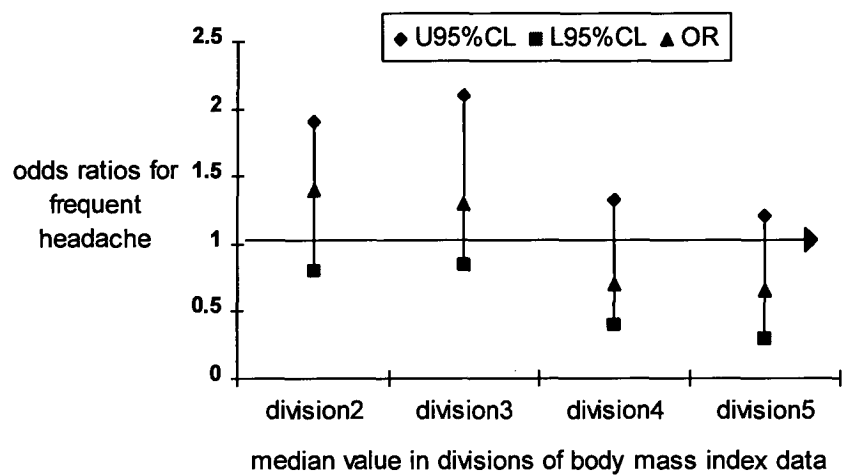


Figure 9.3a. For men: the plot of the odds ratios for frequent headache associated with the median value of the divisions of the data for body mass index.

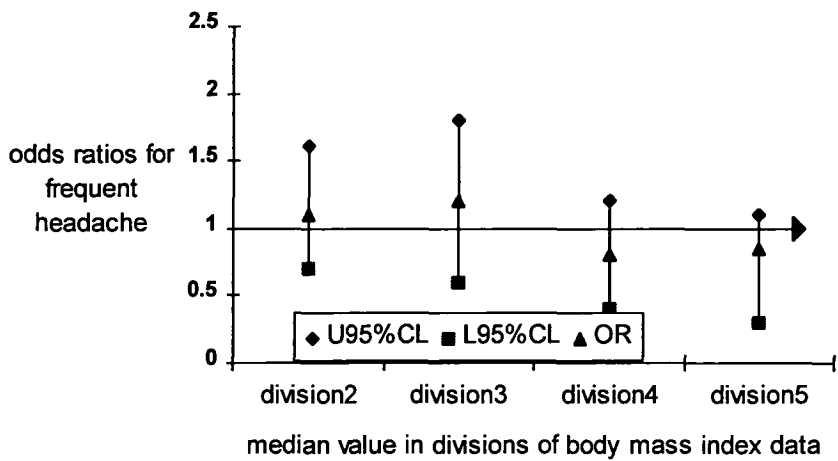


Figure 9.3b. For women: the plot of the odds ratios for frequent headache associated with the median value of the divisions of the data for body mass index.

9.1.4 Breast size

In the logistic regression equation: *Frequent headache* = categories of brassiere cup size, the smallest size (Size A) was designated as the comparison category, for which the odds ratio for frequent headache was set equal to One. This decision was based on biological theory, in which large breasts were associated with headache (Gonzales et al 1993). There was a relatively linear relationship in the data between brassiere cup size and the odds ratios of frequent headache (reported in Table 9.1), and there was a significant test of trend across the four categories ($\chi^2=88.03, p<0.001$). This finding supported biological theory. Moreover, the odds ratios for frequent headache for brassiere cup categories C and D appeared to be significantly different from that of the comparison category (Cup Size A), because the lower 95% confidence limits approximated the value of One.

However, the confidence limits for the odds ratios with frequent headache for brassiere cup categories C and D were wide, an indication of the small numbers of women in them. On this basis, and on evidence of odds ratios for frequent headache that were similarly different from One, categories C and D were combined and expressed as the at-risk category. Brassiere cup size was dichotomised as 1 = brassiere cup size C or D, 0 = brassiere cup size A or B.

Table 9.1. The odds ratios for frequent headache associated with categories of brassiere cup size

	Odds Ratio (95% CL)
size B	1.13 (0.46-2.35)
size C	2.20 (0.89-5.42)
size D	4.22 (1.72-10.38)

9.2 Functional Variables

9.2.1 Mean lateral flexion range of movement

There were gender differences for mean lateral flexion in the strength of association with frequent headache. There was a marked decrease in the odds ratio for frequent headache after the first data division for men, and after the second data division for women (Figure 9.4a and 9.4b). The decrease appeared to be significant because of the approximation of the upper 95% confidence limits to the value One for the second to fifth categories for men, and the third to fifth categories for women. The mean lateral flexion data were divided for men at less than 39 degrees, and for women at less than 36 degrees.

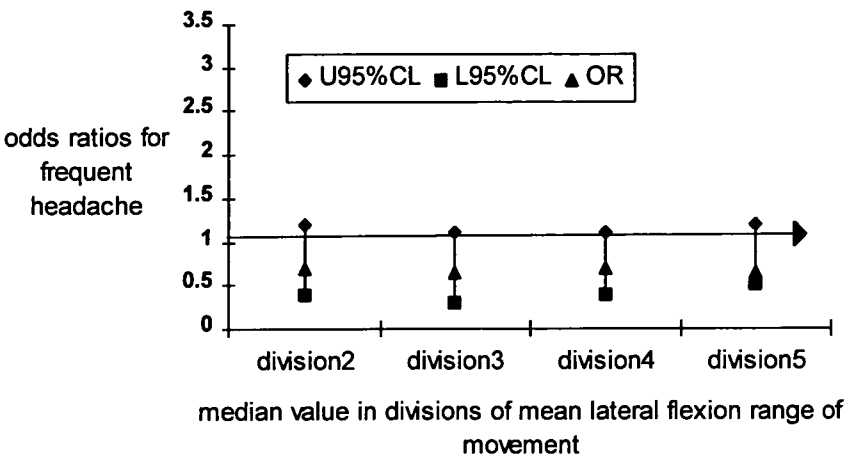


Figure 9.4a. For men: the plot of the odds ratios for frequent headache associated with the median value of the divisions of mean lateral flexion range of movement.

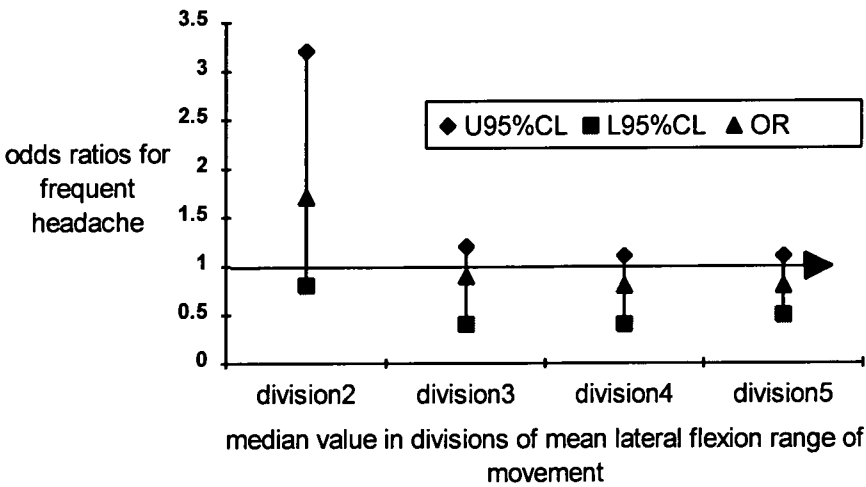


Figure 9.4b. For women: the plot of the odds ratios for frequent headache associated with the median value of the divisions of mean lateral flexion range of movement.

9.2.2 Extension range of movement

There were no observed gender differences for extension range of movement in the estimated strength of association with frequent headache. There was a marked decrease in the odds ratio for frequent headache after the first data division for both men and women (Figure 9.5a and 9.5b). This appeared to be significant because of the approximation of the upper 95% confidence limits to the value One. For both men and women, the extension range of movement data were dichotomised at less than 45 degrees.

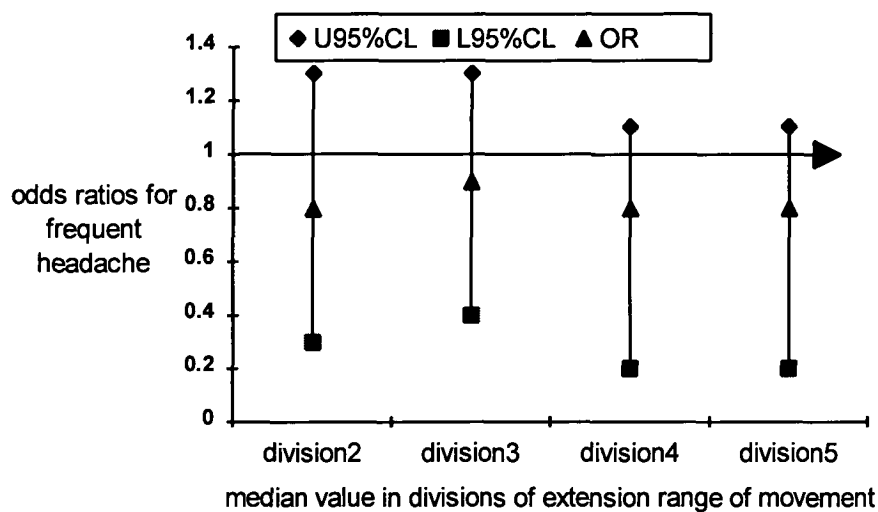


Figure 9.5a. For men: the plot of the odds ratios for frequent headache associated with the median value of the divisions of extension range of movement.

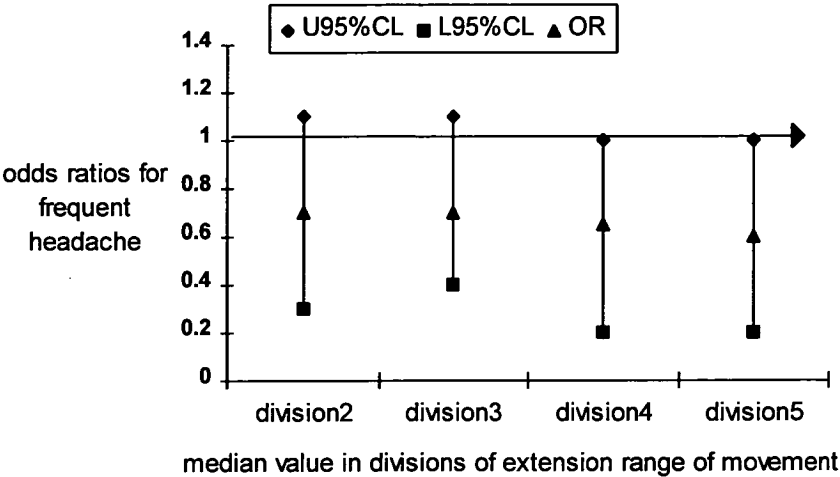


Figure 9.5b. For women: the plot of the odds ratios for frequent headache associated with the median value of the divisions of extension range of movement.

9.2.3 Cervical short flexor muscle endurance capacity

Gender differences were observed for cervical short flexor muscle endurance capacity in the estimated strength of association with frequent headache. For men there was a marked decrease in odds ratios for frequent headache after the first data division, while for women there was a marked decrease after the fourth data division (Figure 9.6a and 9.6b). The data were divided for men at less than 13 seconds, and for women at less than 21 seconds cervical short flexor muscle endurance capacity.

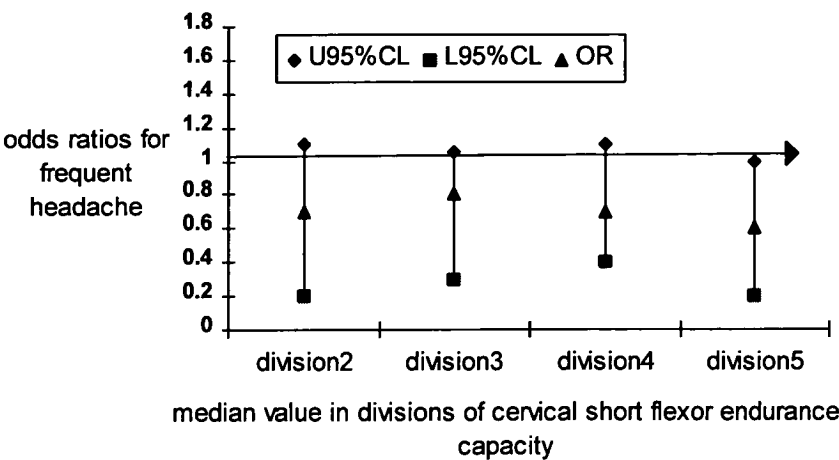


Figure 9.6a. For men: the plot of the odds ratios for frequent headache associated with the median value of the divisions of cervical short flexor endurance capacity.

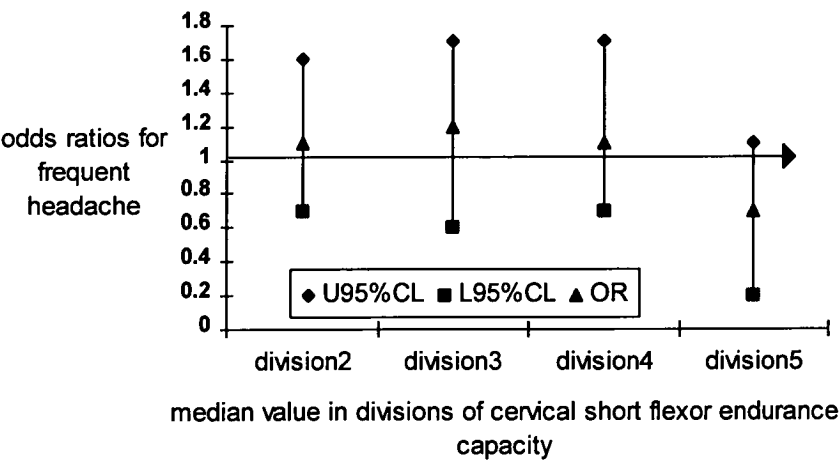


Figure 9.6b. For women: the plot of the odds ratios for frequent headache associated with the median value of the divisions of cervical short flexor endurance capacity

9.2.4 Cervical flexor strength

The Janda strength categories of 2 and 3 were combined into one category, because of the small number of subjects with cervical flexor strength of 2. In the logistic regression equation: *frequent headache* = *categories of cervical flexor strength*, the weakest category (Janda (1983b) (scores 2 or 3) was designated as the comparison category, in which the odds ratio of frequent headache was set equal to One. For both men and women, the odds of headache were markedly less than One, for cervical flexor strength scores of 4 and 5 on the Janda scale (reported in Table 9.2).

Table 9.2. The odds ratios of frequent headache associated with categories of cervical flexor strength

	men	women
scaled value	odds ratio (95% CL)	odds ratio (95% CL)
4	0.44 (0.06-1.35)	0.54 (0.05-1.22)
5	0.54 (0.07-1.42)	0.53 (0.07-1.05)

Cervical flexor strength was dichotomised as:

- 1 = cervical flexor strength, on the Janda scale (1983b), of 2 or 3
- 0 = cervical flexor strength, on the Janda scale (1983b), of 4 or 5

9.2.5 Cervical extensor strength

The Janda strength categories of 2 and 3 were again combined because of the small number of subjects with cervical extensor strength of 2. In the logistic regression equation: *Frequent headache = categories of cervical extensor strength*, the weakest category (Janda score 2 or 3) was again designated as the comparison category, in which the odds ratios for frequent headache was set equal to One. The odds ratios of headache were markedly less than One for cervical extensor strength 4 and 5 on the Janda scale for both men and women (reported in Table 9.3).

Table 9.3. The odds ratios of frequent headache associated with categories of cervical extensor strength

	men	women
scaled value	odds ratio (95% CL)	odds ratio (95% CL)
4	0.36 (0.02-1.22)	0.48 (0.06-1.28)
5	0.32 (0.03-1.23)	0.57 (0.03-1.08)

Cervical extensor strength was dichotomised as:

- 1 = cervical flexor strength on the Janda scale of 2 or 3
- 0 = cervical flexor strength on the Janda scale of 4 or 5

9.3 Physical Variables

All physical variables relevant to this investigation of headache (gender, wearing dentures and wearing glasses) were employed in a binary form. These were classified as risk and no risk on current biological theory. Gender was categorised: 1 = female, 0 = male, wearing dentures was categorised: 1 = wearing dentures, 0 = no dentures, and wearing glasses was categorised: 1 = wearing glasses, 0 = no glasses. The strength of association with frequent headache for categories within the variables of wearing glasses and dentures were not examined, because of the potential for spurious results from small numbers in individual categories, and because muscle performance was believed to underlie the effect of wearing any type of glasses or dentures.

9.4 Social Factors

The odds ratios for frequent headache for men and women in each of the three broad occupational groupings were examined in pairs in the model: *frequent Headache = categories of occupation*. One occupational category in each pair was designated as the comparison group. For men, all of the broad occupational categories entailed similar odds ratios for frequent headache. For women, the 'managerial' and the 'clerical' categories entailed similar odds ratios for frequent headache, but both of these were higher than the odds ratio for headache associated with the 'blue collar' category. On this basis, occupation was broadly categorised for both men and women as: managerial or clerical occupations = 1; blue collar occupations = 0. The output of testing is listed in Table 9.4a for men and Table 9.4b for women.

Table 9.4a. The odds ratios of headache in occupational groups for men

*The term 'cf' is an abbreviation for 'compared with'.

	odds ratio (95% CL)
clerical occupation cf* with managerial	0.73 (0.19-2.41)
blue collar occupation cf managerial	0.77 (0.38-1.56)
blue collar occupation cf with clerical	0.66 (0.19-2.20)

Table 9.4b. The odds ratios of headache in occupational groups for women

	odds ratio (95% CL)
clerical occupation cf with managerial	1.06 (0.43-2.61)
blue collar occupation cf managerial	0.54 (0.18-0.88)
blue collar occupation cf with clerical	0.44 (0.18-1.08)

Key Points

- Little was known regarding the nature of the relationship between headache and its causes. Minimum modelling assumptions are recommended under such circumstances (Rothman 1986). This was the first study to describe the nature of association between headache associated with cervical factors and its causes, and I considered it important to describe the gender-specific association of frequent headache with its causes.

- For some variables, gender-specific cut points were set to account for gender differences in frequency distribution, and to describe differences in association with frequent headache. However, because of wide confidence limits in some instances, further investigation is required before there can be confidence in both the need for gender-specific cut points, and the placement of the cut point.

A summary of the points of division for men and women is provided in Table 9.5.

Table 9.5. A summary of the points of division in the other causes of headache

Proposed cause of headache	men (category = 1)	women (category = 1)
difference in neck length	>= 4 cms	>= 4 cms
body mass index	< 24	< 24
circumference	< 36 cms	< 40 cms
brassiere cup size		cup size C or D
mean lateral flexion	< 39 degrees	< 36 degrees
extension	< 45 degrees	< 45 degrees
cervical short cervical flexor	< 13 seconds	< 21 seconds
muscle endurance (CSFME)		
cervical flexor strength (CFS)	less than grade 4	less than grade 4
cervical extensor strength (CES)	less than grade 4	less than grade 4
occupation	managerial and clerical occupations	managerial and clerical occupations

Chapter Ten

The association between frequent headache, C₇ excursion angles and other causes of headache

This chapter reports on investigations of the estimated strength of association of headache, C₇ excursion angles and the other causes of headache.

Investigations were undertaken for two reasons:

- to identify confounding and/ or modifying effects on the association between C₇ excursion angles and frequent headache that may provide a unifying explanation for the gender differences observed in the relationship between C₇ excursion angles and frequent headache; and
- to inform future studies on headache.

In Section 10.1, the crude odds ratios are reported and discussed for each proposed cause of headache with frequent headache and with C₇ excursion angles. In Section 10.2, tests of homogeneity are reported between strata of the proposed effect modifiers for the association between frequent headache and C₇ excursion angles. Modification effects are discussed. Section 10.3 reports on confounding influences on the association between frequent headache and C₇ excursion angles. In Section 10.4, the effect of helix excursion on the association between C₇ excursion and frequent headache for men, is compared with the effect of breast size and menses on the association between C₇ excursion and frequent headache for women.

10.1 Univariate associations

This section reports on univariate associations of proposed causes of headache, with frequent headache and with C₇ excursion angles. The variables under investigation were breast size and the effect of the menses (for women), and the anthropometric and functional variables, occupation and wearing glasses and dentures (for men and women).

Each proposed cause of headache was investigated as an explanatory term in a model that contained the dummy predictor for C₇ excursion angles as the outcome variable, and as an explanatory term in a second model that contained the dummy predictor for frequent headache as the outcome variable. The association of breast size and the effect of the menses for women, with frequent headache and with C₇ excursion angles are reported in Table 10.1a. The association of the remainder of the variables with frequent headache and with C₇ excursion angles is reported in Table 10.1b.

Table 10.1a. Relevant female variables

Variables	with C ₇		with frequent HA	
brassiere cup size	1.72	0.78-3.86	1.21	0.54 - 2.69
premenstrual tension	0.80	0.33-1.97	1.28	0.98-4.86
aches and pains with menses	0.79	0.32-1.95	3.71	1.51-9.11

Table 10.1b. Other causes of headache for men and women.

Variables	gender	with C ₇		with frequent HA	
		OR	95% CL	OR	95% CL
neck circumference	men	0.27	0.11-0.67	1.22	0.55-3.01
	women	0.75	0.20-2.78	1.63	0.49 - 5.42
neck length difference	men	0.95	0.47-2.89	2.57	1.00 - 5.30
	women	0.58	0.25-1.29	4.03	1.80 - 8.93
body mass index	men	1.99	0.81-4.90	1.82	0.91 - 3.67
	women	1.48	0.60-3.63	0.56	0.28-1.13
lateral flexion	men	1.13	0.51-2.50	1.87	0.84 - 4.18
	women	1.47	0.53-4.48	1.66	0.47-4.14
extension	men	1.66	0.41-6.66	2.85	0.85-9.09
	women	1.09	0.33-3.86	1.11	0.34-2.54
CFS	men	0.26	0.12-0.56	1.87	0.25-14.15
	women	1.13	0.46-2.77	4.22	1.72-10.38
CES	men	0.13	0.04-25.5	1.35	0.41-4.48
	women	0.56	0.25-1.25	3.13	1.55-6.29
CSFME	men	0.34	0.15-0.83	2.13	0.96-4.76
	women	0.79	0.45-1.35	3.56	1.45-6.28
occupation	men	0.72	0.29-1.87	0.78	0.39-1.56
	women	1.16	0.39-10.6	2.48	0.73-5.58
wearing glasses	men	1.63	0.73-3.63	0.74	0.37-1.51
	women	1.51	0.68-3.45	2.72	1.29-5.69
wearing dentures	men	1.67	0.82-3.35	1.60	0.79-3.22
	women	1.02	0.46-2.36	0.97	0.39-1.58

10.1 Summary of univariate findings

10.1.1 With headache

Ten variables had significant associations with frequent headache (in which one of the 95% confidence limits approximated the value of One). Two of these were female-only variables (the effects of the menses). There were unexpected gender differences in the strength and direction of association of some of the other variables with headache. Wide confidence limits were observed in a number of cases. For only two variables (the difference between front and back neck length, and cervical short flexor endurance capacity) were similar estimates of association with headache observed. Gender differences in strength of association were observed for the rest (extension range of movement, cervical flexor and extensor strength and occupation). The effect of occupation on headache was believed to occur via cervical muscle performance and cervical joint range of movement.

10.1.2 With C_7 excursion angles

Only four variables had associations with C_7 excursion angles in which one of the 95% confidence limits approximated the value of One. There were gender differences in the strength and direction of association for every one of these: circumference of neck, cervical flexor strength, cervical short flexor endurance capacity and wearing dentures. The effect of wearing dentures on cervical resting posture was believed to occur via cervical muscle performance and cervical joint range of movement.

The quest for a unifying explanation for the gender differences in the association between helix excursion angles, C_7 excursion angles and headache was therefore focused on the female only variables (breast size and the effect of the menses) and the anthropometric and functional variables for men and women.

10.1.3 The anthropometric variables

10.1.3.1 The difference between front and back length of neck

A large difference between front and back length of neck was proposed in this study as a cause of poor cervical resting posture and an antecedent cause of headache. The sample data provided evidence for such an association with headache, but none for the proposed association with cervical resting posture. The association was protective for women, and no association was observed for men. This finding was unexpected, and identified the need for further investigation of the nature of the association between neck length difference and cervical resting posture, and in particular, gender influences on it.

10.1.3.2 The circumference of neck

A small neck circumference was proposed as an important cause of poor cervical resting posture and an antecedent cause of headache. There was support in the data for one aspect of this proposal for both men and women, that of the association with headache. The weaker estimate of strength of association for neck circumference and headache, than with cervical excursion angles, may be explained by the error in measurement implicit in an antecedent relationship. However, the results did not support the hypothesis that small neck circumference was associated with poor posture (that is, extremely large excursion angles). There was evidence in fact, for a contrary effect, as the association between C₇ excursion angles and neck circumference was protective. There were also unexpected gender differences, as the association between C₇ excursion angles and neck circumference was stronger for men than women.

10.1.3.3 Body mass index

Small body mass was proposed in this study as a cause of poor posture and an antecedent cause of headache. There was evidence for an association in the sample data between body mass and cervical excursion angles for both men and women. However, there were unexpected gender differences in the association with headache. A small body mass index was predictive for men, but protective for women, of frequent headache. This requires further investigation, because such differences do not appear to be biologically plausible. Such differences also lead one to question the specificity of a model for headache in which body mass was a predictor.

10.1.3.4 Breast size

The point and nature of action of breast size in the relationship between cervical excursion and frequent headache was unable to be determined from the cross-sectional data in this study. On the results of univariate analysis, there was little convincing evidence that large breasts were more strongly associated with large C₇ excursion angles than small breasts. There was also little evidence to suggest that women with large breasts had higher odds ratios for frequent headache, when compared with women with small breasts. On these findings, breast size in this sample data was unlikely to confound or modify the association between C₇ excursion angles and frequent headache.

10.1.4 Functional variables

10.1.4.1 Range of movement

Cervical range of movement was proposed as a cause of poor posture and an antecedent cause of headache. The sample data did not provide consistent evidence of such associations for either mean lateral flexion, or extension, range of movement. Moreover, there were gender differences in estimates of strength of association between range of movement, cervical excursion and frequent headache that suggested gender-specific cervical spine mechanisms underlying headache. Poor lateral flexion and extension range of movement are implicated with headache on the grounds that they are indicative of zygapophyseal joint dysfunction, dysfunction of the cervical soft tissues and cervical disc degeneration (Dvorak et al 1988, Panjabi et al 1986, Penning 1978). These pathologies are associated with noxious stimulation of the upper cervical nerves (Bogduk and Marsland 1986). It was not anticipated that these pathologies would be influenced by gender. The association of range of joint movement with headache and cervical resting posture therefore requires investigation with respect to the performance of structures of the cervical spine, and gender effects on such performance.

10.1.4.2 Cervical muscle performance

'Good' performance of cervical musculature is intrinsic to 'good' head-on-neck posture (Janda 1988). The cervical muscles support the position of the head on the neck, making the moment-by-moment adjustments necessary to maintain an erect head, and a horizontal gaze orientation, against the effects of gravity (Hanten et al 1991, Wägenhausen 1971). The performance of the cervical muscles was proposed in this study as the cause of cervical resting posture that underpins all physical and social factors. It was proposed as an antecedent cause of headache, acting via posture.

In the sample data, there was evidence to support associations between measures of cervical muscle performance, frequent headache and C₇ excursion angles. However, once again, gender differences in strength and direction of association were observed. It is recommended that further investigations of the association between cervical muscle performance, cervical resting posture and headache employ measures of muscle synergy, in order to capture more definitive information on the nature of relationships between muscle performance measures during postural manoeuvres.

Questions for further study were raised from this section of the analysis.

- Do both men and women with poor cervical resting posture also have poor muscle strength and poor cervical short muscle flexor endurance?
- Are there gender differences in muscle synergy during postural manoeuvres, and are these related to reporting by women of more frequent headaches than men?

10.1.5 Summary

Variable associations were observed between the explanatory variables, C₇ excursion angles and frequent headache for men and women. In particular, gender differences were observed in a number of the estimated measures of effect, and these require further testing. Variables worthy of further study as causes of frequent headache associated with cervical factors are the anthropometric variables (difference between front and back neck length and neck circumference), functional variables (cervical range of movement and cervical muscle performance) and the effect of the menses for women.

10.2 Homogeneity between strata

For investigations reported in this, and the next section of the chapter, the variables of breast size, occupation, wearing glasses and wearing dentures were treated as confounders and modifiers of the association between established posture and frequent headache. Assumptions underlying these investigations were that the effect of these variables occurred after habitual cervical resting posture became established, and that in this setting these variables were independent predictors of headache. However, under the constraints of the cross-sectional study design, and the failure to enquire about the length of time dentures or glasses were worn, or how long the subject had worked at the occupation, the nature of the association could not be explored.

The crude odds ratio for frequent headache with C_7 excursion angles was stratified for women by brassiere cup size and the variables representing the effect of the menses, and for men and women, by occupation, wearing glasses and wearing dentures. The stratum odds were compared, as a method of identifying the potential for effect modification. The odds ratios for each stratum, and the *p values* from the common odds test (Breslow and Day 1980) are reported in Tables 10.2a and 10.2b. A *p value* of 0.15 or less indicated heterogeneity of effect between strata, highlighting the variable as a potential effect modifier (Rothman 1986, Walter and Holford 1978). On the basis of the observed difference between stratum odds, only the effect of menses for women (measured by aches and pains associated with the menses) had the potential to modify the association between C_7 excursion angles and headache. Confidence could not be placed in this finding however, because of the zero value in one cell, when the dummy predictor for the effect of the menses took the value of One.

On the basis of homogeneity between strata of the remaining variables, the search for modification effects in the sample data was discontinued. There was evidence for the null hypothesis that breast size and the effect of the menses (as measured by premenstrual tension) for women, and occupation, wearing dentures and glasses for men and women, modified the association between C₇ excursion angles and frequent headache.

Table 10.2a. Strata of C₇ excursion and headache for female only variables

	Stratum 1 ¹	Stratum 2	common odds	AOR
	OR (95%CL)	OR (95%CL)	<i>p value</i>	(95%CL)
brassiere cup size	2.54 (0.74-9.04)	2.45 (0.50-13.4)	0.97	2.51 (0.96-6.69)
PMT	2.56 (0.84-8.04)	1.97 (0.27-17.36)	0.80	2.39 (0.92-6.31)
aches and pains with menses	1.88 (0.65-5.50)	infinity	0.18	2.50 (0.91-6.64)

Table 10.2b. Strata of C₇ excursion and headache for other variables

variable	gender	Stratum 1	Stratum 2	common odds	AOR
		OR (95%CL)	OR (95%CL)	<i>p value</i>	(95%CL)
occupation	men	2.38 (0.80-7.15)	2.57 (0.61-11.17)	0.40	2.23 (0.83-5.94)
	women	1.23 (0.18-8.05)	2.86 (0.85-10.17)	0.93	2.45 (1.05-5.75)
glasses	men	1.80 (0.64-5.11)	3.50 (0.75--16.76)	0.43	2.22 (0.97-5.20)
	women	1.30 (0.29-5.83)	3.91(0.9-19.35)	0.25	2.34 (0.87-6.24)
dentures	men	2.00 (0.58-6.97)	3.18 (0.90-11.55)	0.56	2.52 (1.07-5.95)
	women	3.63 (0.93-15.23)	1.53 (0.37-6.52)	0.34	2.42 (0.94-6.41)

1. Stratum 1 represents the dummy predictor of the independent variable = 0

Stratum 2 represents the dummy predictor of the independent variable = 1

10.3 Confounding effects

The association between C₇ excursion angles and headache was adjusted by the proposed confounders. A difference of 10 per cent or greater between crude odds ratio (C.O.R.) and adjusted odds ratio (A.O.R.) was used to detect a confounding effect. The adjusted odds ratio needed to be less than 2.17 or greater than 2.65 for a confounding effect to be detected for women, and less than 2.07 or greater than 2.51 for a confounding effect to be detected for men. A change of 10 per cent was observed only for the effect of wearing dentures for men. The effect of wearing dentures was believed to occur via the performance of the cervical muscles and cervical joint range of movement. Further investigations are indicated into the gender-specific mechanism of the influence of wearing dentures on posture and headache. The results of testing for confounding are reported in Table 10.3a for the female only variables, and in Table 10.3b for the remaining variables.

Table 10.3a. Confounding effects for women of female only variables

	C.O.R.	A.O.R. (95%CL)
	2.43 (0.92-6.41)	
brassiere cup size		2.51 (0.96-6.69)
PMT		2.39 (0.92-6.31)
aches and pains with menses		2.50 (0.91-6.64)

Table 10.3b. Confounding effects of remaining variables

Men	C.O.R.	A.O.R. (95%CL)
	2.29 (1.00-5.30)	
occupation		2.23(0.83-5.94)
wearing glasses		2.22 (0.97-5.20)
wearing dentures		2.52 (1.07-5.95)
Women		
	2.43 (0.94-6.41)	
occupation		2.45 (1.05-5.75)
wearing glasses		2.34 (0.87-6.24)
wearing dentures		2.42(0.94-6.41)

10.4 A unifying explanation for gender-specific effect of helix excursion

This section tests the *post hoc* theory that *the confounding effect of the female (only) variables provides a unifying explanation for gender differences observed in the association between frequent headache and excursion angles*². It was reported in Chapter Eight that the helix excursion angles confounded the crude odds ratio for C₇ excursion angles and frequent headache for men (A.O.R. = 2.01) but not women (A.O.R = 2.41). A unifying explanation of this effect would be provided if for women, the odds ratio from the model: *frequent headache = C₇ excursion angles and helix*, adjusted by the female only variables, was less than 2.17 or greater than 2.65.

². These investigations were conducted under the assumption that helix excursion, breast size and the effect of the menses influenced established posture.

A unifying explanation for the gender-specific effect of helix excursion was unable to be provided by these (female only) variables. The odds ratios for frequent headache with C₇ and helix excursion angles, adjusted by breast size and the effect of the menses, not provide any evidence of a confounding effect by these variables. The results are reported in Table 10.4.

Table 10.4. The confounding effect for women of relevant variables on the model: *frequent headache = C₇ excursion angles and helix*

variables	A.O.R. (95% CL)	<i>p value from the model</i>
C ₇	2.41 (0.98 - 5.92)	<i>p = 0.05</i>
helix	1.27 (0.77-2.09)	<i>p = 0.97</i>
C ₇	2.51 (1.02 - 6.17)	<i>p < 0.05</i>
helix	0.99 (0.49 - 1.99)	<i>p = 0.97</i>
breast size	1.26 (0.62 - 2.53)	<i>p = 0.51</i>
C ₇	2.38 (0.97 - 5.87)	<i>p = 0.05</i>
helix	1.06 (0.47 - 2.36)	<i>p = 0.87</i>
PMT	2.16 (0.97 - 4.80)	<i>p = 0.07</i>
C ₇	2.43 (0.99 - 5.98)	<i>p = 0.05</i>
helix	0.99 (0.45 - 2.22)	<i>p = 0.99</i>
aches etc	3.70 (1.36 - 911)	<i>p = 0.006</i>

10.4.1 A review of the *post hoc* hypothesis

On reflection, one of these models was biologically incorrect. The time effect of independent action of breast size on frequent headache differed from the time effect of independent effect of angular helix excursion. The action of helix excursion was proposed under short-term, 'one-off' conditions, while breast weight, on the other hand, exerts a long-term effect (as a constant force on the anterior chest). However, the time effects of the menses and helix excursion are similar because they can both act in a short-term capacity (albeit cyclic for the effect of the menses). Investigations are required of other effects to provide unifying explanations of the gender effect, observed in this sample data, of excursion angles with frequent headache.

Key Points

- There were gender differences in the strength and direction of associations between C₇ excursion angles, frequent headache and proposed causes of headache. Of most interest were effects involving the anthropometric and functional variables. The performance of the functional variables was believed to underpin the influence on posture and headache of occupation and dentures.
- Under assumptions of independence of effect:
 - breast size and the effect of the menses did not confound or modify the association between excursion angles and frequent headache;
 - wearing dentures confounded the association between frequent headache and C₇ excursion angles for men only;
 - the female only variables did not account for gender differences in the confounding effect of helix excursion on the association between frequent headache and C₇ excursion angles.

Chapter Eleven

Further investigations into frequent headache and C_7 excursion angles

This chapter presents further investigations into headache. Section 11.1 reports on the independence of effect of gender and C_7 excursion angles in frequent headache. Section 11.2 presents a model for frequent headache, and Section 11.3 reports on testing the model on an independent data set.

11.1 Gender effect on headache

There was little evidence that gender (measured as females and males) influenced the association between headache and C₇ excursion angles in the sample data. The estimations of strength of association between C₇ excursion angles and frequent headache were similarly strong (odds ratios of 2.29 (95%CL 1.0-5.30) for men and 2.43 (95%CL 0.94-6.41) for women). Furthermore, there was a high common odds *p value* of 0.92 for gender strata of the association between frequent headache and C₇ excursion angles. This indicated that a modification effect by gender (measured as males and females) was unlikely.

This section sought to examine independence of effect of gender and C₇ excursion angles, with frequent headache. In order to do this, the data for men and women were combined (that is, the data were expressed in a form that was unadjusted for gender). The crude odds ratio for C₇ excursion angles and frequent headache for the combined data was 2.25 (95%CL 1.24-4.12). Adjusting the crude odds ratio by gender provided no evidence of confounding (A.O.R. 2.36 (95%CL 1.27 - 4.36), in that it did not alter the odds ratio by 10 per cent or more. Thus, in this sample data, gender neither modified nor confounded the association between frequent headache and C₇ excursion angles. The strength of association between frequent headache and gender was also estimated for the purposes of this investigation: this being 2.16 (95%CL 1.29 - 3.61). Stratification by C₇ excursion angles provided similarly sized stratum odds ratios. When the C₇ stratum was 0, (that is, C₇ excursion angles were less than 11.5 degrees), the odds ratio of headache with gender was 2.20 (1.20-4.04). When the C₇ stratum was 1 (that is, C₇ excursion angles were equal to, or greater than, 11.5 degrees), the odds ratio of headache with gender was 2.33 (0.75-7.36).

Further evidence to support independence of effect is reported in Table 11.1, by odds ratios of frequent headache with gender in strata of C₇ excursion angles. The odds ratio of the interaction term approximated the product of the (0,1) and (1,0) cells.

Table 11.1. The odds ratios of frequent headache with gender and C₇ excursion angles

	Female	Male
C ₇ >=11.5 degrees	5.32 (2.16-13.06)	2.29 (1.03-5.10)
C ₇ <11.5 degrees	2.20 (1.27-3.86)	1

11.1.1 Summary

Gender and C₇ excursion angles were independent effects with frequent headache in this sample data. However, gender differences in headache prevalence have been described (in previous research, and in this study). The effect of gender on headache therefore requires further investigation using other models. Gender effects on headache may not be best described in terms of males and females. Variables modified by gender may be more appropriate explanatory terms. For instance, a unifying explanation for gender differences in the association between excursion angles and frequent headache may have been provided by examining the effect of the anthropometric and functional variables¹.

¹. Significant gender differences were observed in the association between frequent headache and these causes in the sample data. There were also significant gender differences in the means of these variables, reported in Appendix One.

11.2 A model for frequent headache

This section presents a model for frequent headache. The only explanatory variable in this model was the dummy predictor for C₇ excursion angles. None of the other identified causes of headache impacted significantly on the association between frequent headache and C₇ excursion angles and warranted inclusion in the model. Moreover, the design of the study did not enable the effect of predictors of headache to be sufficiently well described to provide support for proposed biological actions.

Data for men and women were combined for the predictive model. The dummy predictor for C₇ excursion angles was used (≥ 11.5 degrees excursion = 1, < 11.5 degrees excursion = 0) because the same data divisions had been placed for men and women in the C₇ excursion angle data². The construction of the linear discriminant function from the model: *frequent headache = C₇ excursion angles ≥ 11.5 degrees* followed the methodology described by Fletcher et al (1988) and D'Espaignet et al (1990). The model under investigation was:

if P = the probability of a subject having frequent headaches, then:

$$P = \exp(fha) / (1 + \exp(fha))$$

where $fha = X_0 + X_1A$, and A = dummy predictor for C₇ excursion angles. The output of the model is reported in Table 11.2. The model accounted for a significant amount of the deviance, as indicated by the χ^2 statistic associated with the $-2 \log L$ value.

². Categorisation of the C₇ excursion angle data was described in Chapter Seven.

Table 11.2. The parameter estimates from the model for frequent headache

	parameter estimate	S.E.	<i>p value</i>	Deviance
intercept	-0.44	0.14	0.002	-2 log L = 370.26
C ₇	0.81	0.28	0.005	(chi ² = 8.15 ₍₁₎ <i>p</i> =0.004))

11.2.1 The linear predictor

A linear predictor from this model was employed as a discriminant function to identify high risk subjects (those who had a score higher than a pre-determined cut point). Because there was only one predictor variable, the cut point was pre-ordained. For the purpose of developing a predictive score, the parameter estimates were rescaled by 100 for convenience, and a value of 50 was added to each estimate as a constant, to provide a positive value in all instances. 'Rescaling and location shift' preserve the rank order of scores and do not influence discriminatory powers of the model (D'Espaignet et al 1990). When the dummy predictor for C₇ excursion angles took the value of One, the model was sensitive at 82.6 per cent and specific at 32.2 per cent. The score sheet generated from the model is reported in Figure 11.1.

	Score
Constant	6
if C ₇ excursion >= 11.5 degrees	add 131
if C ₇ excursion < 11.5 degrees	add 0
Critical threshold for frequent headache	> 6

Figure 11.1. The scoring sheet from the predictive model

11.3 Testing the model in an independent data set

The availability of data from an independent data set (Set C³, described in Figure 3A in Chapter Three) provided the opportunity to compare proportions of male and female subjects with frequent headache, with those in the main study sample, and to test the predictive powers of the model for frequent headache (Fletcher et al 1988).

11.3.1 The prevalence of headache

In Set C, 33.3 per cent (+/- 12.4 per cent) of male headache sufferers and 50 per cent of female headache sufferers suffered frequent headache. By comparison, in the main data set there were 42.9 per cent of male (+/- 8.9 per cent), and 57.1 per cent of female, headache sufferers. There were similar gender differences in proportions between the data sets.

11.3.2 The predictive power of the model

The model predicted frequent headache in the independent data set with more sensitivity (96 per cent) but with less specificity (18.2 per cent) than in the main study sample from which it was generated. Greater numbers are required in another independent data set to more fully test the validity of the model.

³. Set C comprised 43 subjects who were selected under the same conditions as the main study subjects and who complied with the required exclusion criteria.

Key Points

- There was evidence to suggest that in this data set, the effects of gender (measured as males and females) and C₇ excursion angles were independent causes of headache. The effect of gender on headache required further testing, using variables that were representative of a gender influence, such as functional and anthropometric measures.
- A model for frequent headache was developed using a dummy predictor for C₇ excursion angles as the only exposure term. None of the other causes of headache that were identified in this study, were appropriate for inclusion in the model. The model for frequent headache, developed with the C₇ excursion angle exposure term, had 82.6 per cent sensitivity and 32.2 per cent specificity.
- The findings of this study were tested on the independent data set (Set C).
 - The proportion of men and women with frequent headache in the independent data set (Set C) was similar to that in the main study.
 - The model for frequent headache predicted headache in the independent data set with 96 per cent sensitivity and 18.2 per cent specificity.

Chapter Twelve

Discussion

'When the head aches, all the members partake of the pains.'

Cervantes, Don Quixote (1605).

This chapter discusses the study findings. Section 12.1 provides an overview of the study. Section 12.2 discusses headache associated with cervical factors. Cervical resting posture is discussed in Section 12.3. In Section 12.4, the causal model is reviewed. Section 12.5 discusses biases that may have influenced this study. In Section 12.6 the relevance of the study findings is discussed and in Section 12.7 future directions for study are outlined.

12.1 An overview of the study

This study was motivated by the lack of available information on the prevalence and causes of headache associated with cervical factors. This study found that headache specifically associated with cervical factors was suffered by approximately 63 in every 100 of the never-injured individuals who participated in this study. Headache was reported by study subjects in occasional and frequent forms. One specific cervical resting posture was more strongly associated with frequent headache than any other for both men and women. This was the posture described by angles of excursion of 11.5 degrees or more at the spinous process of C₇, and was characterised by a leading chin with the occiput of the skull caudally rotated within, or slightly anterior to, the gravitational line. There was no clear evidence regarding a specific head posture associated with occasional headache. The strengths of the study were the random sampling of subjects, the size of the sample and the high response rate. The weaknesses in the study were the previously untried measures that were developed to diagnose and measure headache, cervical resting posture and cervical short flexor endurance capacity.

This study described the prevalence and frequency of occurrence of headache specifically associated with cervical factors in a more valid manner than any previous study, because it sought information from a randomly selected sample of subjects, all of whom had equal likelihood of having poor posture and headache (Hill 1965, Susser 1991). In defining the cervical posture most strongly associated with headache, and in identifying and testing causal agents of headache, this study provided baseline information for more specific future investigation (Morabia 1991) into postural influences on headache.

12.2 Headache

12.2.1 The method of diagnosis

An innovative approach was taken to diagnose headache, because of the lack of available diagnostic methods for use in a population-based study. Headache specifically associated with cervical factors had not been studied before using a population-based approach, and thus the issue of an appropriate method of headache diagnosis had not previously been encountered. The diagnostic tool developed for this study may be criticised by some physiotherapists because it did not employ manual therapy examination of the cervical spine. There was however, no convincing evidence that manual therapy examination would enhance the quality of headache diagnosis (Bogduk 1987, Edmeads 1988). Had manual therapy techniques been employed, their use would have raised study questions that could not have been answered using the design of this study. These questions included the validity of manual therapy techniques in accurately identifying the performance of specific spinal structures, the intra- and inter-examiner reliability of findings from manual therapy examination and the correlation between perceived dysfunctional cervical structures (identified by manual therapy techniques) and headache identified by the diagnostic tool.

12.2.2 The diagnostic tool

The diagnostic tool identified one type of headache that was clearly recognised by all subjects (those who suffered from it, as well as those who did not). There was perfect agreement over two months of testing by subjects who did not suffer from headache described by the diagnostic tool. The diagnostic tool identified a headache whose characteristics were stable over time (Nunnally 1972) and which occurred with predictable frequency.

Further testing is required to establish the validity of the diagnostic tool and to test its sensitivity and specificity in other study samples, particularly in individuals with specific 'identifiable pathologic processes or physiological dysfunctions' within the neck (Edmeads 1988, p. 1874). However, there would be difficulty in mounting a study of individuals with specific 'identifiable pathologic processes or physiological dysfunctions' within the neck because of the ongoing debate regarding the validity of any currently employed method of detecting dysfunctional cervical structures (Bogduk 1985, Edmeads 1988, Jull 1988).

12.2.3 The morbidity of headache associated with cervical factors

The morbidity of headache was reported in this study as pain quality and distribution, history and functional activities associated with headache.

All 272 headache sufferers identified the first and third of Jull's criteria (1981) as descriptors of pain distribution and pain quality associated with their headache. These descriptions of pain distribution and intensity have also been attributed to tension-type and migraine headache. The findings of this study therefore support the view that symptoms of both tension-type and migraine headache also occur in headache specifically associated with cervical factors (Jull 1981, Pfaffenrath et al 1987, Sjaastad et al 1983). Moreover these symptoms occur regardless of the frequency with which headache occurs. The differential reporting by occasional and frequent headache sufferers of the remaining two criteria (the occurrence of autonomic symptoms and history of headache) supports the need for longitudinal studies to determine the directionality and nature of association of occasional and frequent headache. The aims of such studies would be to establish whether occasional headache becomes more frequent over time.

Reports of stiff and /or aching necks were not confined to headache sufferers. This descriptor was therefore not sensitive to headache associated specifically with cervical factors. Recall bias may have influenced reports of stiff and aching necks by all subjects. Without further investigation the differential nature of recall bias could not be determined.

Reports of radiological investigations for neck and upper limb symptoms supported the specific involvement of the cervical spine with headache. These reports corroborated observations that crepitation, pain and restriction in neck movements can accompany headache (Centonze et al 1992, Hasvold and Johnson 1993, Pfaffenrath et al 1987, Sjaastad 1987, Weiss 1993). In retrospect, the study would have been improved if specific information had been sought on neck, shoulder and arm symptoms that accompanied headache (Centonze et al 1992, Sjaastad 1987). These symptoms implicate the lower cervical spine in headache pathology, as the nerve roots associated with the shoulder and the arm originate from the lower cervical spine (C₄₋₇) (Cailliet 1989, Basmajian 1980, Moore 1985, Saunders 1982, White and Panjabi 1990).

Headache sufferers most commonly reported that the activities preceding their headaches involved neck extension. Compared with non-headache sufferers, there were high odds that headache sufferers had an increased cervical lordosis in usual resting posture. Gross extension of the cervical spine compresses posterior cervical structures and exert traction on anterior cervical structures (White and Panjabi 1990). Where the cervical lordosis is habitually increased by resting posture, the effects of additional extension on the lordosis may well be implicated in headache mechanisms. Testing is required to further describe the relationship between functional extension of the cervical spine, cervical resting posture and headache.

12.2.4 Exclusion for classic migraine

Two subjects only were excluded from this study for currently taking medication for classic migraine. This represents a much lower percentage of migraine sufferers in this study sample (0.4 per cent) than has been reported in other studies (10 - 20 per cent) which used the IHS migraine criteria to diagnose headache (Mathew et al 1982, Munoz et al 1993, Oleson 1988, Pryse-Phillips et al 1992, Rasmussen 1992, 1993). This study did not diagnose classic migraine headache by the IHS criteria because of the lack of agreement on the classification of headache specifically associated with cervical factors. Moreover, the term 'migraine' is commonly employed to describe any type of headache (Sheftell 1992) and its usefulness when collecting retrospective data was questionable. Several explanations are proposed for the small number of individuals excluded from the study for taking medication for classic migraine headache.

- Sufferers of classic migraine chose to live closer to Hobart (possibly closer to specialist medical services provided in the state capital);
- The prevalence of classic migraine headache in residents of the Huon and Esperance municipalities during 1991-1992 was lower than that in the populations on which the studies on migraine headache had been conducted;
- By chance, a smaller than the usual percentage of classic migraine sufferers were invited to participate in this present study;
- Classic migraine sufferers residing in the Huon and Esperance municipalities during 1991-1992 did not manage their headaches by regular medication;
- The IHS criteria (Oleson 1988) identifies a higher percentage of classic migraine sufferers than does the question on current ingestion of medication for migraine.

12.2.5 Retrospective and prospective headache data

The availability of data from consecutive months of testing provided a unique opportunity to assess the consistency with which headache events were reported by never-injured subjects. The level of agreement between retrospective and prospective reports of the frequency of headache provided the first evidence that headache specifically associated with cervical factors is regularly experienced by never-injured individuals. This finding has particular relevance for single case studies, where the effect of intervention is judged against the natural history of the patient's condition (Riddoch 1990). With this knowledge, the effect of intervention for headache may be more usefully evaluated, as a decrease in headache frequency following intervention may well indicate the success of the intervention.

The nominal scale, used in conjunction with the diagnostic tool, is suggested as a useful method of obtaining retrospective information in clinical settings on the frequency of headache associated with cervical factors. These joint measures of outcome will assist in the development of multicentre studies on the management of headache associated with cervical factors.

12.2.6 Categories of headache

The occasional headache is a recognised feature of tension-type and migraine headache (Kaganov et al 1981, Mathew et al 1982, Saper 1986). This study provided the first evidence that headache associated specifically with cervical factors occurs occasionally as well as frequently in the never-injured population. This study also provided the first evidence that sufferers of occasional headache associated with cervical factors had significantly different functional characteristics when compared with subjects who suffered no headache, and subjects who suffered frequent headache. This phenomenon has previously been reported by Kaganov et al (1981) and

Mathew et al (1982) in tension-type and migraine headache sufferers. Identification of separate levels of occasional and frequent headache associated with cervical factors was of particular importance, as Watson and Trott (1991, 1993) had previously combined those subjects who suffered less than two headaches per month and subjects who suffered no headaches, into a 'no-headache' group. To have adopted their approach without question would have lead to misclassification of Disease in this study sample.

Troup (1988) and Troup and Slade (1985) suggest that gradual degradation of the performance of already dysfunctional structures should be anticipated unless intervention occurs to specifically address the dysfunction. The identification of the separate nature of occasional headache associated with cervical factors raised issues for future study. Do individuals with occasional headache associated with cervical factors continue to suffer occasional headaches throughout life, or does headache frequency increase over time? Do dysfunctional cervical structures become more dysfunctional over time, and are they implicated in headache? Are causal agents of occasional headache also causal agents of frequent headache? Intervention as well as longitudinal studies are needed to address these questions.

Causes of headache particularly inviting further investigation are reduced cervical range of movement and poor cervical muscle performance. These factors are primarily implicated in the degradation of movement quality (Troup 1988). They were associated with headache in the sample data, and they were proposed as more proximate causes of headache than the physical or social factors identified in this study.

12.2.7 The prevalence of headache

Approximately 63 per cent of subjects reported suffering at least one headache event during the period of the study. This was within the same range of the findings of recent population-based studies, in which the prevalence of non-migrainous headache was reported to be 30 - 50 per cent (Bastos et al 1993, Honkasalo et al 1993, Jensen et al 1993, Kaganov et al 1981, Munoz et al 1993, Pryse-Phillips et al 1992, Thompson et al 1993). The prevalence of headache in this sample data provided support for the observation by Honkasalo et al (1993) that headache was of significant public health concern. That approximately 63 per cent of never-injured individuals suffer headache associated with the cervical spine at least once per month raises issues of workplace safety, productivity and quality of life. Furthermore, this study identified the potential for overuse of medication by headache sufferers. Over-the-counter and hence unregulated analgesia was the method of choice of pain relief for subjects reporting occasional and frequent headache. Further study is required to investigate the long-term effects of regular headache and regular medication.

12.3 Cervical excursion angles

12.3.1 The Linear Excursion Measurement Device (LEMD)

The Linear Excursion Measurement Device was developed because there was no standard or reliable method of measuring cervical resting posture in a clinical setting. The LEMD was manufactured at a low cost, and it was time and space efficient. It provided immediate and reproducible measurements of the excursion of two anatomical points on the cervical spine. This information is useful from the perspective of the therapist, the referrer and the patient. The LEMD enables an individual's resting head position to be described with respect to the range of resting head positions found in the never-injured population. The LEMD also offers standardised recording of

assessment and a method by which patients and referrers can receive feedback in quantitative terms on the results of intervention. Further testing is required to determine whether:

- interpretation of the linear measurements of excursion as angles reduces the usefulness of the raw data;
- the use of excursion angles provides a valid description of the habitual resting posture of the cervical spine;
- inter-rater reliability is as high as intra-rater reliability;
- the design of the LEMD and its protocol can be improved; and
- the superior-most tip of the helix of the ear, and the spinous process of C₇ are the most appropriate points for describing the excursion of upper and lower aspects of the cervical spine.

12.3.2 Variability over time of excursion measurements

This study provided the first reported evidence of the variability of measurements of upper and lower cervical excursion. The finding that the measurements provided by the LEMD were in good agreement despite being taken days, or a month, apart, corroborates findings of recent studies where consistency in the cervico-vertebral angle has been demonstrated over one to two weeks (Raine and Twomey 1994, Refshauge et al 1994). Head movement in the sagittal plane has been associated with functional horizontal gaze orientation (Hanten et al 1991). The visual orientation procedure in the LEMD protocol (spotting the letter on the wall chart between flexion/extension movements of the head) was believed to be important in obtaining consistent horizontal placement of the head. However, this requirement may also have lead to measurement error in those subjects whose habitual gaze orientation was downwards. Further investigation is required of the effect on the resting head position of those individuals with habitual downwards gaze when using the Linear Excursion Measurement Device.

It was observed that over time, the excursion of the superior-most tip of the helix of the ear was marginally more variable than that of the spinous process of C₇. This finding was in accordance with reports by Refshauge et al (1994), that the resting angle of the upper cervical spine on the lower cervical spine was more variable than the resting angle of the lower cervical spine on the upper thoracic spine. A flaw in the description of variability over time of excursion was that different subject groups were used for this study. Twenty pilot study subjects provided information on the variability in excursion over days, while 93 (different) subjects provided information on the reproducibility of excursion measurements over a month. The variability of excursion of the upper and lower cervical spine requires more concrete testing by examining the same subjects at different time intervals. In particular, an assessment of the effect of fatigue on the excursion of the resting head is required. The availability of subjects meant that no effort could be made in this study to control for time of day of testing or for lifestyle and/ or occupational demands.

12.3.3 The association between the two excursion angles

An investigation of the data failed to identify a convincing linear association between C₇ and helix excursion angles, for either men or women. In assuming habitual resting head posture, equal and opposite movements of the upper and lower aspects of the cervical spine occurred in less than one quarter of the subjects. Further study is required to more closely investigate the relationship between the excursion of the upper and lower aspects of the cervical spine. The impetus for closer investigation of the mathematical relationship between excursion angles was provided by recent work (Refshauge et al 1994), where a third order polynomial equation appropriately described the inter-relationship between measurements of the resting position of the upper thoracic spine and upper and lower aspects of the cervical spine.

12.4 The causal model

12.4.1 Feasibility of the hypothesis

Before undertaking this study, assurances were sought of the feasibility of the study hypothesis by evaluating evidence for causality using the standards described by Hill (1965) and Susser (1991). Evidence was provided for six of the nine standards, supporting on current knowledge and clinical practice, cervical resting posture as a proximate and plausible cause of headache.

This study described different estimates of the strength of association between occasional and frequent headache and cervical excursion from those that had been anticipated.

12.4.2 The cervical resting posture associated with frequent headache

The belief that there are associations between poor cervical resting posture, cervical dysfunction and frequent headache, underlies treatment approaches taken by physiotherapists. This study confirmed these beliefs, and refined current knowledge by providing the first evidence that identified one specific cervical resting posture as more strongly associated with headache than any other. Further investigation is required to confirm the association with frequent headache of the leading chin posture, with a causally rotated head within the gravitational line, and to identify the biological mechanisms that underlie the relationship. While poor posture is readily observed, and often presents concurrently with headache, this study identified the need to look beyond presenting resting posture for other determining causes of headache. One outcome of this study was to identify variables that were plausibly more proximate causes of headache than cervical resting posture, namely cervical muscle performance and range of cervical movement. As noted previously, these variables require future investigation as primary causes of headache.

12.4.3 Excursion of the superior-most tip of the helix of the ear

This section discusses aspects of the causal model that relate to unexpected estimates of association observed between cervical excursion and headache. *A priori*, a strong association was expected between frequent headache and the excursion of the superior-most tip of the helix of the ear, based on previous studies that described dysfunctional upper cervical joints as a cause of frequent headache (Bogduk 1985, Bovim and Sand 1982, Jull 1986, 1988, Pfaffenrath et al 1987). Several reasons are proposed *post hoc* to account for contrary findings in the sample data:

- Incorrect assumptions underlie the measure of upper cervical excursion. Resting posture of the upper cervical spine may not be best reflected by the measure of excursion of the superior-most tip of the helix of the ear. Neither the resting posture of the upper cervical spine, nor the measure of upper cervical excursion may be reflective of the biomechanical health and performance of the upper cervical joints.
- The superior-most tip of the helix of the ear was chosen as a marker of the upper cervical spine in this study because it lay on the vertical reference line with which the correct cervical lordosis was aligned (Kendall et al 1952). It was readily sighted and it was suited to a clinically based measurement where visualisation, ease of measurement and minimal patient discomfort were important features. Despite these issues, this anatomical point may not have been the most discriminatory point from which to take measurements because it inappropriately described the movement of the upper cervical spine. Future studies should investigate the excursion of other points on the head and cervical spine as better markers of cervical spine excursion. For instance, the height of the superior-most tip of the helix of the ear may have differed between men and women, thus reducing the ability

of the LEMD to accurately describe, for all subjects, the excursion of the upper cervical spine. Braun and Amundsen (1989) employed the tragus of the ear as one reference point for the cranio-vertebral angle. The tragus was considered to be a standard distance from the first cervical vertebra (Loebl 1967). If a method could be developed to measure the excursion of the tragus of the ear in a clinical setting, it may prove to be more useful in providing measurements of the excursion of the upper cervical spine for both men and women than the superior-most tip of the helix of the ear.

- Very small degrees of translation occur in the upper cervical spine during postural movement (White and Panjabi 1990, Worth 1988). Regardless of the chosen anatomical point, the measure of excursion at the upper cervical spine taken in a clinical setting may be too gross to appropriately describe the performance of the upper cervical spine.

12.4.4 Occasional and frequent headache

This section discusses the lack of support in the data for commonality of association between extreme angular excursion and headache. On theoretical grounds, cervical resting posture was a plausible cause of both occasional and frequent headaches. It is suggested that occasional and frequent headache are measures of the same headache type, on evidence that two only of Jull's criteria were not reported by occasional headache sufferers, (those of the presence of autonomic / vascular symptoms and a prolonged history of headache), and that the headache characteristic was stable. Proposals for the lack of a common resting posture link between categories of occasional and frequent headache are provided:

- The use of the same exposure terms in models for frequent and occasional headache was inappropriate. In order to apply broad modelling arguments to the excursion angle data, the excursion angles were investigated only with frequent headache. Preliminary evidence indicated that this association was the one most likely to yield a convincing point of data division. Misclassification of the exposure terms for use in a model in which occasional headaches were the outcome variable would have obscured the true strength of the association (Rothman 1986).
- The mechanisms underlying occasional headache differ significantly from those underlying frequent headache. For instance, cervical excursion may not have been the most proximate cause of both occasional and frequent headache.

Alternative causal mechanisms are proposed to inform future studies.

Proposal 1.

Occasional headache has been proposed at the beginning of a progressive degenerative path for tension-type and migraine headache (Kaganov et al 1981, Mathew et al 1982). If the same proposal is made for headache specifically associated with cervical factors, it follows that progression down the causal path plausibly degrades the performance of cervical structures. Habitually poor cervical resting posture results, as described by extremely large excursion angles. Habitually poor cervical resting posture in this causal path is more proximal to frequent headache than occasional headache. This proposal is illustrated in Figure 12.1.

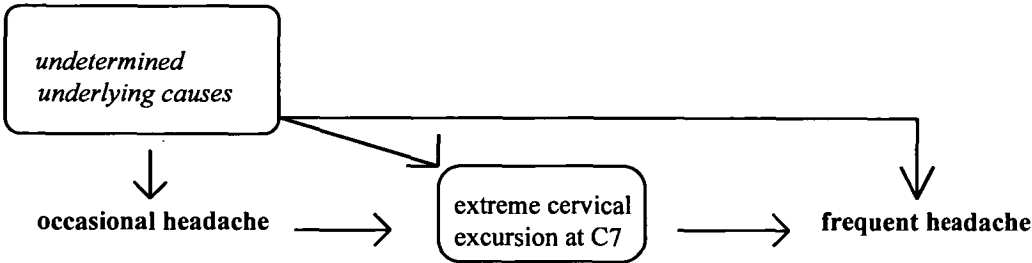


Figure 12.1. *Post hoc* Proposal 1 for the association between cervical resting posture (described by extreme cervical excursion angles), occasional and frequent headache

Proposal 2.

Habitually poor cervical resting posture develops concurrently with occasional headache. Their development is interlinked and they are correlates of each other. Both are causes of frequent headache. This proposal is illustrated in Figure 12.2.

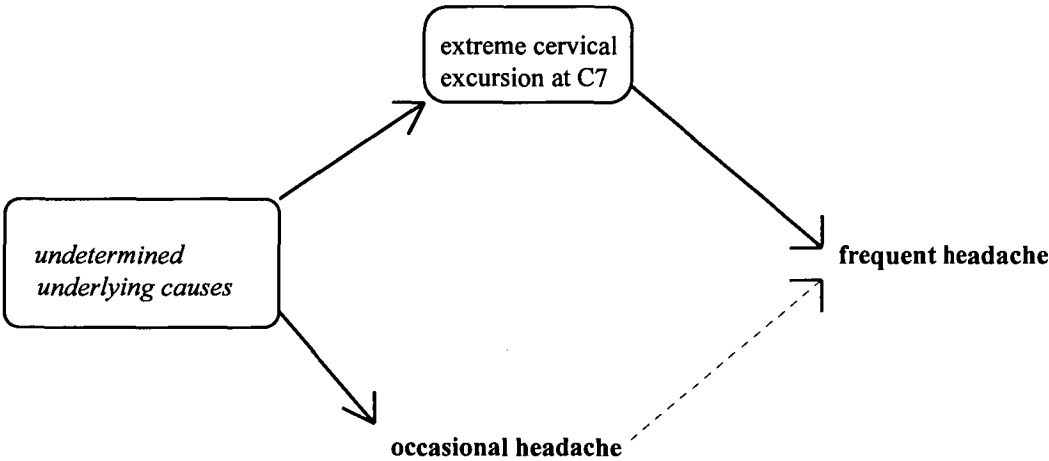


Figure 12.2. *Post hoc* Proposal 2 for the association between cervical resting posture (measured by extreme cervical excursion angles), occasional and frequent headache

12.4.5 Other causes of headache

A number of causes of headache, other than cervical resting posture, were identified and tested in this study. Because this was the first population-based study on headaches associated with cervical factors, this step was taken to inform future studies. Moreover, these causes were identified in an effort to control for confounding, and to identify modifying influences on the association between headache and excursion angles. The cross-sectional study design, and the failure of the study to supply historical information (when the effect of breast size, glasses, dentures and occupation first occurred), precluded description of the nature of the influence of these other causes with headache.

Two scenarios were proposed for this study, under which the association of headache with its other causes was investigated.

- The first scenario involved the influence of other causes of headache, during postural development, and during moment-by-moment manoeuvres of adult posture. In this scenario, the majority of the proposed causes of headache were correlates of resting posture, acting in an antecedent fashion to headache.
- In the second scenario, selected variables were proposed as independent causes of headache, acting in specific circumstances after posture had become established.

The anthropometric and functional variables were proposed as underpinning the influence of physical and social causes of headache. As such, they are proximate causes of headache on other causal paths. There is a particular need to study the nature of the influence of cervical muscle performance on headache and posture in a woman with large breasts, or in an individual who wears glasses and dentures, or who pursues a particular occupation.

Poor cervical muscle performance reduces the stability of the cervical spine, and habitually poor cervical posture and neck pain are believed to inhibit neural transmissions to the cervical muscles (Gurumoorthy 1991, Janda 1988, Richardson 1989). The performance of the cervical muscles was proposed as an important predictor of posture, but the nature of its effect may well differ when posture is developing than when posture is established. For physiotherapeutic intervention for 'poor' posture to be effective, a clearer understanding of the influence over time of cervical muscle performance seems imperative.

Gender differences in the variables that were associated with frequent headache underscored the importance of considering men and women separately, particularly in intervention studies. For men, poor mean lateral flexion was shown (in Chapter Six) to be a consistent factor in both occasional and frequent headache. Lateral flexion is an indicator of the health of the upper cervical spine (White and Panjabi 1990), and therefore the range of movement and associated biomechanics of the upper cervical spine may be particularly important in male headache mechanisms. On the other hand, for women, cervical muscle performance ratio was shown (in Chapter Six) to be a consistent factor in occasional and frequent headache. These findings further highlight the need for investigations of cervical muscle performance and resting posture.

12.4.6 Mechanisms associating large excursion angles with headache

This section proposes specific causal mechanisms for the association between extremely large angles of C₇ excursion and frequent headache for men and women. Photographs of subjects with habitually large angles of excursion at C₇ depict a large cervical lordosis. This implicates the lower cervical spine in habitual extension (White and Panjabi 1990). In habitual extension the C₅₋₆ joint is considered to move paradoxically into flexion, a position which would biomechanically embarrass the structures of the lower cervical spine (Dvorak et al 1988, Panjabi 1974, White and Panjabi 1990). The pathology considered to underlie headache specifically associated with cervical dysfunction includes noxious stimulation of the upper three cervical nerve roots (Bogduk 1981, Kerr 1962, Sjaastad et al 1983). Such noxious stimulation has been attributed to upper cervical joint dysfunction (Bogduk 1981, Jull 1981, 1985), one cause of which has been proposed as poor cervical posture (Ayub et al 1981, Jull 1988, Trott 1988). An association between dysfunction of structures of the lower cervical spine, poor cervical posture and headache has not benefited from as much attention.

Neural fibres associated with the trigeminal nerve have been found as low as C₃ (Bogduk 1987), and plausibly have even lower sympathetic connections (Sahrmann 1987). These connections could provide a mechanism for direct stimulation of the trigemino-cervical nucleus via structures in the middle and lower cervical spine. The anterior and posterior cervical ligaments provide a continuous connection between the upper, middle and lower segments of the cervical spine. The effects of events such as exaggerated paradoxical translation of C₅ on C₆ would thus affect the biomechanics of the entire cervical spine and would alter local histopathology and neural transmissions (Gurumoorthy 1991).

That extension activities were most commonly reported as precursor to headache supports an association between headache and habitual extension of the lower cervical spine in usual resting posture. The extension posture implicit in functional activities such as cleaning windows or painting the ceiling plausibly increases compression of cervical structures in subjects whose lower cervical spine is already habitually extended.

However, a recent roentgenographic study on posture in subjects with, and without, tension-type headaches, reported that the headache subjects exhibited marked cervical spine protraction (Nagasawa et al 1993). As the present study obtained only four responses from subjects with present headache, the resting posture of subjects in present pain could not be effectively described or investigated separately. Further study is required to investigate the resting position of the cervical spine during periods of pain and no pain in order to describe biomechanical responses of cervical structures.

12.4.7 Chronic daily headache

It has been suggested that the chronic daily headache is a separate headache type that involves complex and interactive causal mechanisms (Rapoport 1992, Solomon 1992). Troup (1988) suggested that once pain becomes chronic, underlying causal mechanisms became difficult to disentangle. Daily headache was not investigated in this study because:

- the variability over two months of testing of reports of daily headaches indicated that the daily headache sufferers were appropriately combined with other frequent headache sufferers;
- there were no differences in emotional or functional characteristics when comparing daily headache sufferers with other frequent headache sufferers;

- there was a small number of subjects who retrospectively reported daily headache in this study. The power of causal observations made separately on this group would have been low.

Future studies that more specifically investigate mechanisms and causes of daily headache are indicated.

12.5 A discussion of biases affecting the study

12.5.1 External validity

The municipal electoral roll was chosen as a source of subjects for this study as it was believed to be a comprehensive record of the population in a given region. However, the comprehensive nature of the Huon and Esperance municipal rolls in 1991-1992 was unknown. On personal enquiry before commencing this study, the State Electoral Office in Tasmania estimated that municipal rolls contained approximately 85 per cent of eligible voters. At the time of the study, there was a stable population in the Huon Valley, and high rate of local involvement in local government, employment and recreational opportunities. On this basis I estimated that the municipal electoral rolls in these municipalities contained the names of a higher than average percentage of eligible voters, thus reducing the opportunity for sampling bias. The external validity of the study was enhanced by random selection of subjects.

12.5.2 Internal validity

This section discusses biases that may have affected the internal validity of the study. Sackett (1979) has listed many biases that can effect the estimation of measures of effect. While it is difficult to differentiate between some of Sackett's biases (Rothman 1986), his list was used as the main reference in this section because of its comprehensive nature.

12.5.2.1 Selection bias

Selection bias encompasses all those factors that cause the relationship between exposure and disease to differ between the participants in the study, and those who were invited to participate, but did not do so (Greenland 1989, Rothman 1986, Sackett 1979). Specific exclusion factors were applied in this study so that subjects had an equal likelihood of poor posture and headache (Kelsey et al 1986). The exclusion factors were employed to define the headache type, not to restrict exposure status. Moreover, all subjects had access to telephone and/ or postal services, and all were literate. The subjects who participated in the study were likely to be representative of those who were invited to participate, but did not do so. There was a high participation rate in both the prevalence study and the study that tested the reproducibility of measurements (94.9 per cent and 93 per cent respectively). In addition, there was no missing data, as all the questionnaires were fully completed at the time of interview.

12.5.2.3 Measurement bias

Recall bias was a potential source of error in this study. Non-differential misclassification of headache, or of factors associated with headache morbidity, may well have occurred (Rothman 1986). Differential misclassification of Disease was considered unlikely as headache was measured independently from posture (Exposure). While subjects may have under- or over-estimated headache frequency retrospectively, bias most likely occurred in a similar manner across the exposed and non-exposed groups. This effect would have biased any measure of association towards the null value (Copeland et al 1977).

Efforts were made to minimise recall bias. The time over which information was gathered was the same for all subjects (i.e. one month retrospective recall, and one month prospective headache diary). This standardised an important indicator of the accuracy of recall (Klemetti and Saxen 1967), that of time lapse between disease onset and the collection of information. The same prompts were given to all subjects in the form of the diagnostic tool. While the level of compliance when completing the headache diaries was unknown, the extent of agreement between the diaries and the recalled headaches suggested that *compliance bias* had not occurred (Sackett 1979). Consideration of the *prevalence -incidence bias* (Sackett 1979) provided a possible explanation for the occasional headache state. There is incomplete knowledge of the pathology associated with headache, and the limited nature of previous studies on headaches specifically associated with cervical factors suggested that frequent headache may represent a late outcome. The sufferer of occasional headaches may not have come to notice in previous studies because of the infrequent and intermittent nature of the headache.

The methods of recording and interpreting the headache data may have involved two sources of bias. Although the seven level nominal scale was more expansive than any other retrospective headache scale reported in the literature, it was *insensitive* (Sackett 1979) in that it provided only seven choices of headache frequency. The insensitiveness was particularly evident when headaches occurred more frequently than once a week. There were only two further choices on the scale - once every two days and daily. Those subjects whose headaches occurred, say, twice a week, were disadvantaged.

However, the scale was specifically developed to identify the occasional headache sufferer. The definition of the frequent headache sufferer had been well described in previous studies (Edeling 1982, 1988, Pfaffenrath et al 1987, Watson and Trott 1991, 1993) and needed little further clarification. In identifying the occasional headache sufferer, the scale achieved its intention. It identified that some subjects suffered headaches every couple of months, and some suffered them monthly. In this respect, the scale was not affected by insensitivity bias, because no finer definitions of headache frequency could be made of the period of time falling between no headaches and two headaches per month. On the other hand, *scale degradation bias* may have been incurred in two instances, when:

- the daily headache diary data were compared the retrospective seven-level headache data, and
- the seven-level retrospective headache data from 427 subjects were collapsed into three headache levels in order to test the proposed causal model.

Collapsing categories of outcome on the basis of small numbers in order to gain precision tends to lead to misinterpretations of rate ratio estimations. The misinterpretations usually trend towards the null value, leading to observations of lack of effect (Rothman 1986). In this study, the categories were collapsed to describe particular types of headache presentation, not on the basis of small numbers. In particular, the homogeneity of the frequent headache group was demonstrated, and those subjects with occasional headaches were considered on clinical grounds, and on the basis of testing, to be significantly different from those subjects who reported no headaches at all.

Several other biases reported by Sackett (1979) may have influenced the measurements. *Apprehension bias* may have been present, particularly affecting the measurements of headache frequency, cervical muscle performance, cervical range of movement and cervical excursion. The effect of apprehension bias may provide a reasonable explanation for the systematic improvement noted in the retest measurements of cervical short flexor endurance and cervical range of movement.

Unacceptability bias may have affected the completion of the General Wellbeing Schedule, given the private and/ or intrusive nature of some of the questions. This bias may have affected the responses of those subjects who had significant emotional difficulties at the time of interview, in that the true nature of their emotional wellbeing may not have been reflected by their answers.

New measures were developed for the purpose of this study, these being the diagnostic tool for headache, the posture measuring device and the measure of cervical short flexor endurance. *The sensitivity of the instrument* was unknown as there were no available alternative measures against which to validate or calibrate the new measures. However, the results of testing did not indicate a lack of sensitivity, in that the characteristics described by the new measures were stable, and the agreement between measurements over time was high. In particular, the sensitivity of the test of cervical short flexor endurance was demonstrated, in that the systematic change in endurance capacity over time may well have been induced by the test itself, by a learnt response, or by proprioceptive influences.

12.5.2.3 Confounding bias

Attempts were made in this study to identify confounding effects on the association between cervical excursion angles and headache. There was a lack of biological theory to inform this study, and potential confounders were identified from a literature search that took account of studies on 'whiplash', headache and posture. The majority of the proposed causes of headache were plausibly related to headache via posture. A scenario was described for the purpose of this study, in order to clearly define the nature of confounding influences. Confounding was considered possible only when the variable acted independently with headache, on established cervical resting posture. However, this scenario could not be tested due to the cross-sectional nature of the data. For this reason, this study also contributed little to discussion on antecedent or intermediate effects with headache. The nature of the association of causes of headache, via moment-by-moment postural manoeuvres, or via established cervical resting posture, requires specific longitudinal studies.

There was concern that the literature search failed to identify important independent causes of headache (that were not correlates of posture), and that this study thus did not control for important confounding influences on posture and headache. A further literature search is recommended to more clearly define the biological theory associated with the action of potential causes of headache, and to identify other causes of headache associated with cervical factors.

12.6 The relevance of the study findings

12.6.1 To never-injured individuals

The prevalence of headache reported in the current study is similar to that reported in recent population-based studies on tension-type headache (Hasvold and Johnsen 1993, Honkasalo et al 1993). The findings have implications for headache sufferers, their family, employers, health and legal professionals.

Claims have been made that poor cervical posture is effectively improved by physiotherapy intervention (Jull 1988, Trott 1988), although the poor cervical resting posture most closely associated with headache was not identified. This study provided a description of the particular cervical resting posture in the never-injured population that was associated with frequent headache.

Identification in a clinical setting of patients with important causes of headache will ensure more selective application of physiotherapy techniques. In this study, extremely large cervical excursion angles were identified as one cause of headache, and this has provided baseline information for future studies. This study has provided the incentive for further studies to identify and test more proximal causes of headache than cervical resting posture, and to evaluate the results of physiotherapy intervention.

12.6.2 To injured subjects

This study provided an indication of the prevalence of headache in gender-specific age groups of the never-injured population. This will inform a court when determining appropriate financial settlements for pain and suffering in personal injury claims. This is the only aspect of the study that has immediate relevance to the court room setting. Attempts to predict the likelihood of headache when the injured individual is believed to have 'poor' habitual cervical resting posture is of no benefit either to the court or the injured individual. Injury affects habitual resting posture because of the effects of pain, swelling, muscle spasm and/or joint dysfunction. In a medico-legal setting, it would be unusual to have evidence of pre-and post injury status of head on neck posture. Physiotherapy treatment for injury is frequently provided to eliminate present pain and reduce perceived dysfunction. That pain and dysfunction may have been present prior to the injury can be overlooked. Grooming of post-injury symptoms for the purposes of maximising legal settlements has been noted (Mendelsohn 1979). While injury to the neck interferes with joint and soft tissue performance, the performance of the cervical spine prior to the accident may have implications for the long term outcome from injury. The Quebec Task Force (Spitzer et al 1995), in its extensive recent monograph, identified the lack of knowledge of causal agents for ongoing neck and head pain in the general population and in those individuals following 'whiplash' injuries.

12.7 Future investigations

A number of further studies have been highlighted in the discussion chapter.

Moreover, this study needs to be repeated in order to confirm:

- the 'at-risk of headache' status of the resting head posture where the chin leads and the head is caudally rotated within the gravitation line;
- the use of excursion of anatomical points on the head and neck as a method of describing resting cervical posture in a clinical setting;
- the strength of association between extremely large cervical excursion angles and frequent headache specifically associated with cervical factors;
- gender differences in headache mechanisms that involve cervical resting posture.

An agreed method of specifically detecting cervical dysfunction associated with headache is required. Studies are also required to investigate differences in cervical excursion of individuals who suffer from distinctly different headache types (i.e. daily headache, tension-type headache, migraine headache). These studies are required to test whether there is one headache type uniquely associated with cervical mechanisms, or whether a degree of cervical involvement is implicated in all headaches.

Chapter Thirteen

Conclusion

13.1 Summary of the study and its findings

This study reported on investigations into headache that was specifically associated with cervical factors suffered by never-injured individuals.

Cervical resting posture was investigated as a cause of headache.

13.1.1 New Measures

New measures of cervical resting posture, headache and cervical short flexor muscle endurance were developed for this study, as there were no standard or reliable measures available in a clinical setting.

- The Linear Excursion Measurement Device (LEMD) was designed to measure cervical resting posture. It provided linear measurements of the excursion of anatomical points on the head and neck as habitual resting posture was assumed from a corrected vertical position. Assumptions were made that excursion angles, an expression of combined horizontal and vertical measurements of excursion, described the differential movement of the upper and lower aspects of the cervical spine. Testing established the excursion measurements taken by the device, from two anatomical points on the cervical spine as reproducible over time. The device was appropriate to a clinical setting, and was believed to describe cervical resting posture.
- A list of pain criteria for headache, reported to be specifically associated with cervical dysfunction (Jull 1981), was adapted as the diagnostic tool. This tool employed three criteria, all of which needed to be reported for a headache diagnosis to be conferred. The criteria described neck pain and/ or stiffness, waking with headache and

suffering headache after prolonged and sustained activity of the neck. The diagnostic tool was appropriate to a questionnaire format and described a particular headache type that was readily recognised by all subjects.

- A multilevel, time-based, nominal scale was developed to facilitate retrospective recall of the frequency of headaches in the preceding month.
- A method was developed to obtain objective measurements of cervical short flexor muscle endurance in a clinical setting.

13.1.2 Parameters under which the study was conducted

This study investigated a poorly researched area. There was little biological theory to support causal mechanisms, and parameters to guide the study were developed from scant existing knowledge.

- Six of nine criteria for causality (Hill 1965, Susser 1991) supported the feasibility of an association between cervical resting posture and headache.
- Causes of headache specifically associated with cervical factors (other than cervical resting posture) were identified from various sources of the literature. Biological mechanisms for the association with headache were proposed. Causes of headache were categorised into anthropometric, functional, physical, social and emotional. The influence of anthropometric and functional variables was believed to underpin physical and social causes of headache.

Causes of headache

In order to more clearly define the relationship of headache and its causes, two scenarios were proposed.

1. The proposed causes of headache were correlates of cervical resting posture, acting in an antecedent fashion to headache, via cervical resting posture.
2. Selected variables acted independently with headache in specific circumstances where the effect of the variable occurred after posture was established.

13.1.3 Study findings

This study found that:

- occasional and frequent headache associated with cervical factors (headache occurring less frequent than twice per month, and headache occurring twice or more per month, respectively) is suffered by never-injured individuals.
- occasional headache sufferers are significantly different from no headache, and from frequent headache, sufferers. For men, there was a significant decrease across headache categories in mean lateral flexion. For women, there was a significant decrease across headache categories in cervical muscle performance.
- both occasional and frequent headache were reported consistently over two months.
- at least one event of headache per month was reported by 63.7 per cent of subjects in the study. Occasional headache was reported by 55.5 per cent of the headache sufferers and frequent headache was reported by the remaining 45.5 per cent of headache sufferers.

- there were significant gender differences in the prevalence of headache. Fifty-five per cent of occasional headache sufferers, and 57.1 per cent of frequent headache sufferers, were women. Similar proportions of men and women with headache were observed in the second (independent) data set of forty-three subjects.
- more frequent than occasional headache sufferers reported a long history of headache, and reported autonomic symptoms with their headaches (i.e. vision disturbance, nausea etc).
- over-the-counter analgesia was the method of choice of headache management for both occasional and frequent headache sufferers.
- headache sufferers commonly described functional activities involving cervical extension as precursor to their headaches.
- there was a lack of biological theory to guide appropriate treatment of explanatory variables, when applying them to a model with headache as the outcome variable. This necessitated close examination of the nature and strength of association with headache. Dose-response curves were published for all relevant causes of headache.
- extremely large angles of excursion at the superior-most tip of the helix of the ear (greater than, or equal to, 6 degrees), and at the spinous process of C₇ (greater than, or equal to, 11.5 degrees) were more strongly associated with headache than any other. Dummy predictors of the excursion angles were developed at these cut-points. Extremely large excursion angles occurring at the spinous process of C₇ and the superior-most tip of the helix of the ear described a head held within the gravitational line, with a leading chin and a caudally rotated skull.
- there was a weak association between occasional headache and the excursion angles at both anatomical points. The association between helix excursion angles and frequent headache was stronger for men

than for women, while the association between C₇ excursion angles and frequent headache was similarly strong for men and women. Attention was focused on frequent headache in subsequent investigations because this association was the most convincing one. The crude odds ratio for frequent headache with C₇ excursion angles for men was 2.29 (95%CL 1.03 - 5.01), and for women was 2.41 (95%CL 1.00 - 5.81).

- under the scenario of independent action with headache (a 'one-off' situation), helix excursion angles confounded the association between frequent headache and C₇ excursion angles for men (A.O.R. 2.01) but not for women (A.O.R. 2.41). A modification effect under the multiplicative model was observed for men but not for women.
- none of the proposed causes of headache modified the association between frequent headache and C₇ excursion angles.
- wearing dentures confounded the association between frequent headache and C₇ excursion angles for men, but not for women
- a unifying explanation for gender differences in the association between frequent headache and excursion angles was not provided by the confounding effect of the female-only variables (breast size and the effects of the menses).
- gender and C₇ excursion angles were independent effects on headache in the sample data. Variables that require further investigation to explain gender differences in headache associated with cervical factors are the anthropometric and functional variables. These particularly include cervical muscle performance and cervical range of joint movement.
- the model for frequent headache, where a dummy predictor for C₇ excursion angles was the only exposure term, was sensitive to 82.6

per cent, and specific to 32.2 per cent in the sample data. It predicted less efficiently in an independent data set.

13.2 The original (motivating) study question

This study was conceived after an experience in court, when I was unable to answer a question about the frequency of headaches, associated with the neck, that were usually experienced by middle aged men who had never suffered a neck injury. There was nothing in the literature to inform my response, and hence I identified the need for this study. This study has therefore provided the first known baseline data on the frequency in the never-injured population, of headache associated with the cervical spine. Such information will provide a court room reference when determining appropriate settlement of personal injury claims, as it provides a basis from which to make decisions regarding reasonable reimbursement for pain and suffering following injury.

13.3 Specific relevance of this study to physiotherapists

This study succeeded in its aim of providing information that was relevant to clinical physiotherapists. Information on headache prevalence will prove useful in a clinical setting, as a baseline measure of 'usual' occurrence of headaches. A successful outcome of physiotherapeutic intervention for headache could be a decrease in headache frequency to approximate the 'usual' age/ gender specific frequency of headache, rather than to aim for achieving nil occurrence.

The method of measuring cervical resting posture with the LEMD provides a way of objectively measuring and describing head posture, which will be useful in determining whether intervention for individual postural abnormalities has effected a change. Moreover, this study provides for the first time, a description of different 'poor' head postures, and in so doing, challenges long held physiotherapeutic descriptions of head posture. This

information will prompt physiotherapists to be more specific in their description of resting head position, and provides the impetus for further studies on head posture and its determinants. The identification of one resting head posture that is more strongly associated with headache than any other will direct further investigation into mechanisms of headache associated with posture.

13.4 The value of population-based research for the study question

A population-based approach to research provided the only avenue for investigating the question of the prevalence of headache. Studies to date, on headache associated with the cervical spine, had reported only on the numerator population, and therefore had not investigated the extent of the problem in individuals who had not suffered an injury to the cervical spine, or in those injured individuals who had not presented for medical or physiotherapeutic assistance in dealing with their pain. Nevertheless, these studies were important precursors in the investigation of headache associated with the cervical spine, as they identified and described the problem. This present study, in taking a population-based approach, was a logical progression from these early works. However, the cross-sectional design of this present study necessarily placed constraints on the interpretation of its findings. For instance, headache measurement was potentially compromised because it was based on recall, using verbal prompts. As such, there were also inherent difficulties in measuring headache intensity, and in describing headache pain, because few subjects suffered headache at the time of measurement. Furthermore, the directionality of the association between headache and posture was unable to be investigated, and therefore causal inferences could not be made.

13.5 Future directions

In order to more fully describe effects on posture and headache, additional population-based studies as well as other research approaches need to be undertaken. The prevalence and incidence of headache associated with the cervical spine, and the presentation of, and variability in, individual cervical resting postures, require investigation using longer term studies that take repeated measures over time. Future research approaches could also involve cadaver studies to identify and test upper and lower cervical spine pathologies that relate to headache. Intervention studies are also required, to describe the effect of specific postural changes, or improvements to muscle performance or joint range of movement, on headache status. Such investigations could be undertaken using informed single case studies, as well as controlled clinical trials, which seek to describe postural changes in an objective manner as well as measure a decrease in headache frequency after postural intervention.

This study identified that headache is suffered by a significant proportion of never-injured individuals. Physiotherapists therefore owe it to their patients and to their profession, to continue to seek answers to this affliction.

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APPENDIX ONE

The results from preliminary testing

Table of Contents

Part 1	Age and gender of subjects in the study sample	II
Part 2	Representativeness of Subset B1 of the main study sample	IV
Part 3.	Gender differences in study variables	V1
Part 4.	The effect of age on headache	VIII

Part 1. Age and gender composition of subject groups

Set A. The pilot study subjects

Age group	female	male
< 40 years (young)	4	6
40-59 years (middle)	3	4
60+ years (old)	2	1
Total	9	11

Set B. The main study subjects

Age group	female	male
18-40 years (young)	99	94
40-59 years (middle)	76	99
60-83 years (old)	36	23
Total	211	216

Subset B1. The reproducibility study subjects

Age group	female	male
< 40 years (young)	21	31
40-59 years (middle)	12	20
60+ years (old)	5	4
Total	38	55

Set C. The independent study subjects

Age group	female	male
< 40 years (young)	6	8
40-59 years (middle)	12	10
60+ years (old)	3	3
Total	21	22

Part 2. The representativeness of Subset B1 of the main study sample

Headache and cervical excursion angles of the 93 subjects in Subset B1 were compared with those of the remaining subjects in the main study sample (Set B - Subset B1).

Headache

Headache was ordinally scored (1-7) for the purpose of this analysis. There was similar variance in headache data when comparing the two groups of subjects (for women, $F=1.52_{(37,169)}$, $p=0.08$) and for men, $F=1.17_{(54,157)}$ $p=0.47$). No significant differences were detected between mean headache frequency between the two groups for men or women. A high level of association was observed between scores. These findings indicated that the headache characteristic measured in Subset B1 was the same as that measured in Set B. Subset B1 was representative of Set B with respect to headache frequency. The results of testing are provided in Table 1A.

Table 1A. Headache frequency (SD)

NB SD = Standard Deviation

	mean Subset B1 (SD)	mean (Set B - Subset B1) (SD)	<i>t</i> value	<i>p</i> value	<i>r</i> ² statistic
female	3.29 (2.04)	2.80 (1.65)	1.62	0.11	0.86
male	2.52 (1.77)	2.28 (1.64)	0.85	0.37	0.84

Excursion angles

There was equal variance in the excursion angle data for Subset B1 and the remainder of the study sample (women, $F=1.02_{(37,169)}$, $p=0.89$, and men, $F=1.07_{(54,157)}$, $p=0.79$). There was no significant difference between the means of the excursion angles of C_7 or the superior-most tip of the helix of the ear. The results of testing are reported in Tables 2Ai and ii.

Table 2Ai. Excursion angles at C_7

	mean Subset B1 (SD)	mean (Set B - Subset B1)(SD)	t-test	<i>p value</i>	r^2 statistic
female	8.62 (4.75)	8.42 (4.73)	0.23	0.81	0.91
male	7.41 (4.44)	7.80 (4.55)	-0.43	0.67	0.90

Table 2Aii. Excursion angles at the helix of the ear

	mean Subset B1 (SD)	mean (Set B - Subset B1) (SD)	t-test	<i>p value</i>	r^2 statistic
female	5.63 (3.34)	6.47 (3.20)	-2.19	0.10	0.86
male	4.82 (3.17)	5.64 (3.54)	-1.55	0.12	0.89

Part 3. Gender differences in the study variables

i. Headache frequency

The ordinal headache scale (1-7) was employed for the purpose of testing gender differences. The data demonstrated equal variance between men and women ($F=1.08_{(210,215)} p=0.58$). Mean headache frequency for women was 2.88 (S.D. 1.74) and for men 2.35 (S.D. 1.67). These means were significantly different ($t_{(1)}=3.20 (p=0.001)$).

ii. Excursion angles

There were gender differences in both excursion angles. Women had a larger mean than men for C₇ excursion angles ($p=0.09$) as well as a significantly larger mean than men for helix angles ($p=0.04$). The means and *t*-test results are reported in Table 3A.

Table 3A. Gender differences in C₇ and helix excursion angles (degrees)

angle	gender	mean	S.D.	<i>t</i> score	<i>p</i> value
C ₇	female	8.45	4.72	1.67	0.09
	male	7.70	4.51		
helix	female	6.08	3.32	2.02	0.04
	male	5.41	3.46		

ii. Occupation

Subjects were employed in all of the eight occupational categories described in the Australian Standard Classification of Occupations (Australian Bureau of Statistics 1984). These categories were:

Occupation	Alpha. Code	Number Code
Managerial	M	1000 - 1999
Professional	P	2000 - 2999
Para professional	PP	3000 - 3999
Trades persons	T	4000 - 4999
Clerical	C	5000 - 5999
Service Industry	SI	6000 - 6999
Plant Operators	PO	7000 - 7999
Blue Collar Workers	BCW	8000 - 8999

The gender and age distribution of subjects into these occupational categories is reported in Tables 4Ai and ii, and illustrated in Figure 1A.

Table 4Ai Gender/ age/ occupation category distribution

		Code								Total
Age group		M	P	PP	T	C	SI	PO	L	
< 40 years	female	11	12	3	9	27	4	6	26	
	male	9	7	4	18	7	0	12	36	
40-59 years	female	9	17	4	1	19	6	3	14	
	male	30	7	5	16	5	3	10	23	
60+ years	female	14	7	2	0	5	1	0	2	
	male	10	3	0	2	2	0	2	4	
Total	female	34	36	9	10	40	11	9	42	191
Total	male	49	17	9	36	14	3	24	63	215

Significantly different proportions of men and women were noted when the 95% Confidence Limits around the proportion did not embrace 0.50. Significantly more women than men were employed in professional, clerical and service industry occupations. Significantly more men were employed as trades persons and plant operators. No significant differences in gender proportions were noted for managerial and para professional occupations. Those occupational categories that had significantly different proportions have a stippled background in the following table.

Table 4Aii. Significant gender differences in occupational category

	Proportion of Women	Upper and Lower 95% CL
Managerial	0.41	0.32 - 0.50
Professional	0.67	0.55 - 0.79
Para professional	0.50	0.38 - 0.72
Tradespersons	0.22	0.11 - 0.33
Clerical	0.79	0.70 - 0.86
Service Industry	0.79	0.59 - 0.99
Plant Operators	0.27	0.13 - 0.41
Blue Collar Workers	0.40	0.31 - 0.49

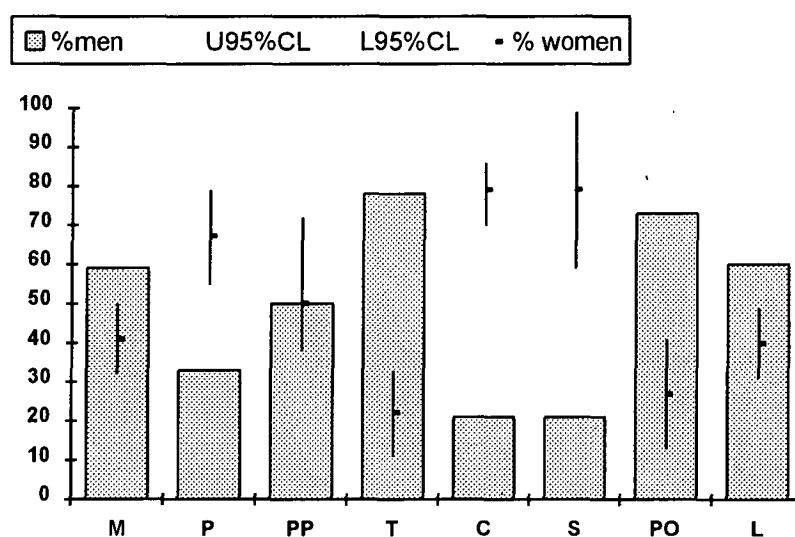


Figure 1A. Gender / occupation distribution of 427 subjects. The 95%CL are graphed for the proportion of women in each occupational group, and the proportion of men is illustrated as the column.

iii. Anthropometric Measures

Significant gender differences were observed in all the anthropometric measures. Women were significantly shorter and lighter and had significantly shorter and slimmer necks. The results of testing are reported in Table 5A.

Table 5A. Anthropometric measurements

variable		mean	S.D.	<i>t</i> score	<i>p</i> value
female	height (cms)	166.39	7.16	-16.89	0.001
male		179.09	8.32		
female	weight (kgs)	65.93	11.67	-11.86	0.001
male		79.75	12.41		
female	circumference (cms)	34.39	2.81	-20.09	0.0001
male		39.94	2.91		
female	front length of neck (cms)	15.86	1.67	-4.63	0.0001
male		16.63	1.81		
female	back length of neck (cms)	13.13	1.51	-4.57	0.0001
male		13.81	1.57		

iv. Functional variables

There were significant gender differences in the measurements of cervical short flexor endurance and cervical muscle strength. The results of testing are reported in Table 6A.

Table 6A. Gender differences in the functional variables

variable		mean	S.D.	t score	p value
female	extension (degrees)	56.27	9.58	0.002	0.99
male		56.27	10.00		
female	lateral flexion (degrees)	41.42	6.65	1.75	0.08
male		40.25	7.09		
female	CSFME (secs)	14.41	5.01	-7.06	0.0001
male		17.79	4.91		
female	Cervical Flexor Strength (Scale 1-5)	3.96	0.73	-11.69	0.0001
male		4.68	0.53		
female	Cervical Extensor Strength (Scale 1-5)	4.44	0.54	-10.01	0.0001
male		4.88	0.33		

v. Emotional Wellbeing Schedule.

The individual elements of the General Wellbeing Schedule, and the overall Schedule (GWS), were examined for gender differences. Significant gender differences were observed in the means of the elements of depression, wellbeing, self control and vitality. No overall gender differences were found for the Schedule. The results of testing are reported in Table 7A.

Table 7A. Gender differences in the Emotional Wellbeing Schedule

	variable	mean	S.D.	<i>t</i> score	<i>p</i> value
Female	anxiety	17.98	2.16	0.58	0.55
Male		17.86	2.21		
female	depression	16.67	3.30	-3.07	0.002
male		17.64	3.17		
female	wellbeing	8.79	2.63	3.24	0.001
male		7.94	2.73		
female	self control	5.83	2.38	2.52	0.01
male		5.24	2.44		
female	health	7.62	1.74	0.03	0.97
male		7.62	1.84		
female	vitality	13.10	2.36	-2.26	0.02
male		13.64	2.57		
female	GWS	70.02	4.59	-0.15	0.88
male		69.95	5.00		

Part 4

The effect of age on headache

Headache categories were ordinally scaled 1 - 7 for the purpose of this analysis.

Age was considered as a continuous variable. Gender-specific linear regression models were constructed to provide preliminary evidence regarding the relationship between age and headache.

For women, the variation in headache frequency that was explained by age was 0.2% ($r^2=0.002$, $F=0.40$). For men, age explained 0.09% of the variation in headache frequency ($r^2=0.0009$, $F=0.19$). On these findings, age exerted little effect on headache occurrence for either men or women in the sample data.

APPENDIX TWO

The documents used to collect the data

Table of Contents

Part 1	The initial measuring session documents	XV
	i. the consent form	XV
	ii. the headache diagnosis tool	XVI
	iii. the questionnaire (including the General Wellbeing Schedule)	XVII
	iv. the objective measurement sheet	XXV
	v. the headache diary.	XXVI
Part 2	The remeasuring session documents	XXVII
	i. the questionnaire	XXVII
	ii. the objective measurement sheet	XXVIII

Part 1. The documents used at the initial measuring session

i. Consent Form

Consent Form

I, consent to participate in this study conducted by Miss Karen Grimmer. I understand that Miss Grimmer is a physiotherapist investigating headache for the purpose of her PhD studies at the University of Tasmania. I understand that this study is being conducted in accordance with the ethical guidelines of the University of Tasmania, and that I can withdraw my consent at any time. I understand that all information obtained in this study is confidential and that I will not be identified by name once testing is completed.

Signed

Date

ii. Headache diagnosis tool

To be given to the subject at the testing session

Headache Description

1. You have pain at the back of the skull and/or in the neck when you have this headache.
2. You often wake up with this type of headache.
3. This type of headache is usually associated with:
 - holding your head in the one position for a long time; and/ or
 - constant neck movement; and/ or
 - with tension.

Other symptoms

- A. This headache can affect any area of your head or face, either all over it, on just in one spot.
- B. This headache is a moderately severe ache, or as a feeling of tightness or heaviness in your head.
- C. This headache is *sometimes* accompanied by:
 - disturbances in vision;
 - nausea;
 - dizziness on movement;
 - jaw aches; or
 - ear symptoms such as ringing, deafness or aching.
- D. This type of headache is often suffered off and on for years.

iii. The initial questionnaire and measurement sheet

ID Number _____

**PLEASE FILL IN THIS QUESTIONNAIRE TO THE BEST OF YOUR ABILITY.
YOUR ANSWERS ARE COMPLETELY CONFIDENTIAL, AND YOUR NAME
WILL BE REMOVED FROM THE RECORDS AS SOON AS TESTING IS
COMPLETED.**

1. Your Name _____

2. Home phone number _____

3. Today's Date

		199
--	--	-----

4. Are you male or female? M F

5. Your Date of Birth

		19
--	--	----

6. What is your marital status?

a. living with your partner

b. living alone

c. living only with children

d. living at home with parents

e. shared accommodation (flatting)

f. other _____

7. In which country were you born? _____

8. How many days a week would you usually travel in a motor vehicle? _____

9. In what capacity do you usually travel?

- a. driver
- b. passenger in a car
- c. passenger in a bus
- d. other _____

10. During the last four weeks what was your working status?

- a. full time regular daytime worker
- b. full time shift worker
- c. part-time daytime worker
- d. part-time shift worker
- e. housewife or househusband only
- f. a student
- g. not working

11. What was your financial status?

- a. wage or salary earner
- b. unemployed
- c. retired from the workforce
- d. self employed

12. What is (or was) your occupation? _____

13. If you are retired or unemployed, how long is it since you worked at this employment?

- a. less than one month
- b. 2-3 months
- c. 4-6 months
- d. 7-12 months
- e. more than 12 months

14. Please list all the tablets you are taking at the moment? (e.g. for blood pressure etc)

15. Has your neck ever been X-rayed?

Yes

No

16. If it has been X-rayed, why was this? _____

17. Do you regularly take any dietary supplements?

Yes

No

18. What are they?

a. calcium

b. Vitamin C

c. Vitamin B complex

d. multivitamins and minerals mixture

e. codliver oil

f. iron

g. any other _____

19. Do you usually wear glasses?

Yes

No

20. Why do you wear them?

a. reading only

b. distance vision only

c. all the time

21. Do you wear dentures?

Yes

No

If so, what dentures do you wear? (i.e. partial top, complete top etc).

22. You have been given descriptions of three symptoms of a particular type of headache. In the last month, did you suffer from any headache which matched all three of these symptoms?

Yes	No
-----	----

23. If you have a headache like this, what are the most effective things you do to get rid of it?

- a. take pain killers (what do you take?) _____
- b. relax, mediate etc.
- c. lie down
- d. use hot or cold packs or compresses?
- e. do neck exercises
- f. put on a collar
- g. don't need to do anything - they just go away
- h. other _____

24. How often did you have a headache like this in the last month?

- a. didn't have a problem with them
- b. daily
- c. every couple of days
- d. once a week
- e. about once every two weeks
- f. about once a month
- g. every couple of months or so

25. Did you suffer from any stiff necks in the past month?

Yes	No
-----	----

26. Did you suffer from any aching necks in the past month?

Yes	No
-----	----

If you answered Yes to Question 22, please circle on the sheet provided any of the other symptoms which you associate with your headache.

27. What is your favourite interest or hobby?

- a. outdoor physical (bushwalking, skiing, tennis, water sports etc)
- b. indoor physical (badminton, judo, gym. work, swimming etc)
- c. physical activities on your own (gardening, carpentry, etc.)
- d. quiet hobbies (reading, cards, handcrafts, TV etc)
- e. others _____.

28. How often do you participate in this hobby?

- a. once or more a day
- b. a few times a week
- c. once a week
- d. once every two weeks
- e. once a month
- f. every one to two months

29. Do you associate any particular activity at work or at home with the headaches which were described on the sheet?

Yes

No

What is it? _____

30. How regularly do you take part in recreational sport?

- a. daily
- b. a few times a week
- c. once a week
- d. once a fortnight
- e. once every 3 - 4 weeks
- f. irregularly
- g. not at all

31. What sports do you play at the moment? _____

THANK YOU VERY MUCH FOR YOUR HELP.

The General Well-Being Schedule

a. Name (Last, first, middle)	b. Deck No. <div style="text-align: center;">171</div>	c. Sample No. <div style="text-align: center;">— — — — —</div>	d. Sex 1 <input type="checkbox"/> Male 2 <input type="checkbox"/> Female
-------------------------------	---	---	--

READ — This section of the examination contains questions about how you feel and how things have been going with you. For each question, mark (X) the answer which best applies to you.

1. How have you been feeling in general? (DURING THE PAST MONTH)	1.	(001)	1 <input type="checkbox"/> In excellent spirits 2 <input type="checkbox"/> In very good spirits 3 <input type="checkbox"/> In good spirits mostly 4 <input type="checkbox"/> I have been up and down in spirits a 5 <input type="checkbox"/> In low spirits mostly 6 <input type="checkbox"/> In very low spirits
2. Have you been bothered by nervousness or your "nerves"? (DURING THE PAST MONTH)	2.	(002)	1 <input type="checkbox"/> Extremely so -- to the point where I could not work or take care of things 2 <input type="checkbox"/> Very much so 3 <input type="checkbox"/> Quite a bit 4 <input type="checkbox"/> Some -- enough to bother me 5 <input type="checkbox"/> A little 6 <input type="checkbox"/> Not at all
3. Have you been in firm control of your behavior, thoughts, emotions OR feelings? (DURING THE PAST MONTH)	3.	(003)	1 <input type="checkbox"/> Yes, definitely so 2 <input type="checkbox"/> Yes, for the most part 3 <input type="checkbox"/> Generally so 4 <input type="checkbox"/> Not too well 5 <input type="checkbox"/> No, and I am somewhat disturbed 6 <input type="checkbox"/> No, and I am very disturbed
4. Have you felt so sad, discouraged, hopeless, or had so many problems that you wondered if anything was worthwhile? (DURING THE PAST MONTH)	4.	(004)	1 <input type="checkbox"/> Extremely so -- to the point that I have just about given up 2 <input type="checkbox"/> Very much so 3 <input type="checkbox"/> Quite a bit 4 <input type="checkbox"/> Some -- enough to bother me 5 <input type="checkbox"/> A little bit 6 <input type="checkbox"/> Not at all
5. Have you been under or felt you were under any strain, stress, or pressure? (DURING THE PAST MONTH)	5.	(005)	1 <input type="checkbox"/> Yes -- almost more than I could bear or stand 2 <input type="checkbox"/> Yes -- quite a bit of pressure 3 <input type="checkbox"/> Yes -- some -- more than usual 4 <input type="checkbox"/> Yes -- some -- but about usual 5 <input type="checkbox"/> Yes -- a little 6 <input type="checkbox"/> Not at all

<p>6. How happy, satisfied, or pleased have you been with your personal life? (DURING THE PAST MONTH)</p>	<p>6. (006) 1 <input type="checkbox"/> Extremely happy - could not have been more satisfied or pleased 2 <input type="checkbox"/> Very happy 3 <input type="checkbox"/> Fairly happy 4 <input type="checkbox"/> Satisfied -- pleased 5 <input type="checkbox"/> Somewhat dissatisfied 6 <input type="checkbox"/> Very dissatisfied</p>
<p>7. Have you had any reason to wonder if you were losing your mind, or losing control over the way you act, talk, think, feel, or of your memory? (DURING THE PAST MONTH)</p>	<p>7. (007) 1 <input type="checkbox"/> Not at all 2 <input type="checkbox"/> Only a little 3 <input type="checkbox"/> Some -- but not enough to be concerned or worried about 4 <input type="checkbox"/> Some and I have been a little concerned 5 <input type="checkbox"/> Some and I am quite concerned 6 <input type="checkbox"/> Yes, very much so and I am very concerned</p>
<p>8. Have you been anxious, worried, or upset? (DURING THE PAST MONTH)</p>	<p>8. (008) 1 <input type="checkbox"/> Extremely so -- to the point of being sick or almost sick 2 <input type="checkbox"/> Very much so 3 <input type="checkbox"/> Quite a bit 4 <input type="checkbox"/> Some -- enough to bother me 5 <input type="checkbox"/> A little bit 6 <input type="checkbox"/> Not at all</p>
<p>9. Have you been waking up fresh and rested? (DURING THE PAST MONTH)</p>	<p>9. (009) 1 <input type="checkbox"/> Every day 2 <input type="checkbox"/> Most every day 3 <input type="checkbox"/> Fairly often 4 <input type="checkbox"/> Less than half the time 5 <input type="checkbox"/> Rarely 6 <input type="checkbox"/> None of the time</p>
<p>10. Have you been bothered by any illness, bodily disorder, pains, or fears about your health? (DURING THE PAST MONTH)</p>	<p>10. (010) 1 <input type="checkbox"/> All the time 2 <input type="checkbox"/> Most of the time 3 <input type="checkbox"/> A good bit of the time 4 <input type="checkbox"/> Some of the time 5 <input type="checkbox"/> A little of the time 6 <input type="checkbox"/> None of the time</p>
<p>11. Has your daily life been full of things that were interesting to you? (DURING THE PAST MONTH)</p>	<p>11. (011) 1 <input type="checkbox"/> All the time 2 <input type="checkbox"/> Most of the time 3 <input type="checkbox"/> A good bit of the time 4 <input type="checkbox"/> Some of the time 5 <input type="checkbox"/> A little of the time 6 <input type="checkbox"/> None of the time</p>
<p>12. Have you felt down-hearted and blue? (DURING THE PAST MONTH)</p>	<p>12. (012) 1 <input type="checkbox"/> All of the time 2 <input type="checkbox"/> Most of the time 3 <input type="checkbox"/> A good bit of the time 4 <input type="checkbox"/> Some of the time 5 <input type="checkbox"/> A little of the time 6 <input type="checkbox"/> None of the time</p>

<p>6. How happy, satisfied, or pleased have you been with your personal life? (DURING THE PAST MONTH)</p>	<p>6. (006) 1 <input type="checkbox"/> Extremely happy -- could not have been more satisfied or pleased XXIII 2 <input type="checkbox"/> Very happy 3 <input type="checkbox"/> Fairly happy 4 <input type="checkbox"/> Satisfied -- pleased 5 <input type="checkbox"/> Somewhat dissatisfied 6 <input type="checkbox"/> Very dissatisfied</p>
<p>7. Have you had any reason to wonder if you were losing your mind, or losing control over the way you act, talk, think, feel, or of your memory? (DURING THE PAST MONTH)</p>	<p>7. (007) 1 <input type="checkbox"/> Not at all 2 <input type="checkbox"/> Only a little 3 <input type="checkbox"/> Some -- but not enough to be concerned or worried about 4 <input type="checkbox"/> Some and I have been a little concerned 5 <input type="checkbox"/> Some and I am quite concerned 6 <input type="checkbox"/> Yes, very much so and I am very concerned</p>
<p>8. Have you been anxious, worried, or upset? (DURING THE PAST MONTH)</p>	<p>8. (008) 1 <input type="checkbox"/> Extremely so -- to the point of being sick or almost sick 2 <input type="checkbox"/> Very much so 3 <input type="checkbox"/> Quite a bit 4 <input type="checkbox"/> Some -- enough to bother me 5 <input type="checkbox"/> A little bit 6 <input type="checkbox"/> Not at all</p>
<p>9. Have you been waking up fresh and rested? (DURING THE PAST MONTH)</p>	<p>9. (009) 1 <input type="checkbox"/> Every day 2 <input type="checkbox"/> Most every day 3 <input type="checkbox"/> Fairly often 4 <input type="checkbox"/> Less than half the time 5 <input type="checkbox"/> Rarely 6 <input type="checkbox"/> None of the time</p>
<p>10. Have you been bothered by any illness, bodily disorder, pains, or fears about your health? (DURING THE PAST MONTH)</p>	<p>10. (010) 1 <input type="checkbox"/> All the time 2 <input type="checkbox"/> Most of the time 3 <input type="checkbox"/> A good bit of the time 4 <input type="checkbox"/> Some of the time 5 <input type="checkbox"/> A little of the time 6 <input type="checkbox"/> None of the time</p>
<p>11. Has your daily life been full of things that were interesting to you? (DURING THE PAST MONTH)</p>	<p>11. (011) 1 <input type="checkbox"/> All the time 2 <input type="checkbox"/> Most of the time 3 <input type="checkbox"/> A good bit of the time 4 <input type="checkbox"/> Some of the time 5 <input type="checkbox"/> A little of the time 6 <input type="checkbox"/> None of the time</p>
<p>12. Have you felt down-hearted and blue? (DURING THE PAST MONTH)</p>	<p>12. (012) 1 <input type="checkbox"/> All of the time 2 <input type="checkbox"/> Most of the time 3 <input type="checkbox"/> A good bit of the time 4 <input type="checkbox"/> Some of the time 5 <input type="checkbox"/> A little of the time 6 <input type="checkbox"/> None of the time</p>

iv. Objective Measurements

32. Height _____ cms

33. Weight _____ kgs

34. Cervical short flexor endurance capacity _____ secs

35. Cervical flexor strength

1	2	3	4	5
---	---	---	---	---

36. Cervical extensor strength

1	2	3	4	5
---	---	---	---	---

37. Length of neck

i. occiput to C₇ _____

ii. point of chin to zythisternum _____

38. Circumference of neck _____

39. Range of Neck Movement

Extension _____

L Lat. flex _____

R Lat. Flex _____

40. Trunk height in corrected sitting _____

41. Trunk height in resting sitting _____

42. Vertical Distance measured by LEMD

a. helix _____

b. C₇ _____

43. Horizontal Distance from LEMD

a. helix _____

b. C₇ _____

ANGLES
helix
C ₇

44. Resting pulse _____

47. If female, Bra size _____

48a. Do you normally suffer from Pre-menstrual Tension?

Yes	No
-----	----

48b. Do you associate any aches and pains in your neck with your menstrual cycle?

Yes	No
-----	----

v. Headache Diary

Diary

PLEASE KEEP THIS DIARY FOR THE NEXT MONTH.

Circle the days on the enclosed calendar, starting on .../.../..., when you have a headache which matches the description provided.

Headache Description

You have pain at the back of the skull and/or in the neck when you have this headache.

You often wake up with this type of headache.

This type of headache is usually associated with:

- holding your head in the one position for a long time; and/ or
- constant neck movement; and/ or
- with tension.

January

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

December

S	M	T	W	T	F	S
31				1	2	
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

February

S	M	T	W	T	F	S
					1	2 3
	4	5	6	7	8	9 10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29		

Part 2 The documents used at the remeasuring session**i. Questionnaire**

NB: *The General Wellbeing Questionnaire is not included in this questionnaire, although subjects completed it at the second test session. It has already been reported in Part 1.*

ID Number _____

1. Did you suffer from any stiff necks in the past month?

Yes	No
-----	----

2. Did you suffer from any aching necks in the past month?

Yes	No
-----	----

3. How regularly did you take part in recreational sport in the past month?

- a. daily
- b. a few times a week
- c. once a week
- d. once a fortnight
- e. once every 3 - 4 weeks
- f. irregularly
- g. not at all

General Wellbeing Questionnaire

OFFICE USE ONLY

Were any headaches recorded on the diary?

Yes	No
-----	----

The number of headaches recorded in the headache diary

--

ii. Objective Measurements

5. Height _____ cms
6. Weight _____ kgs
7. Cervical short flexor endurance capacity _____ secs
8. Cervical flexor strength

1	2	3	4	5
---	---	---	---	---

9. Cervical extensor strength

1	2	3	4	5
---	---	---	---	---

10. Length of neck
- i. occiput to C₇ _____
- ii. point of chin to zyphisternum _____
11. Circumference of neck _____
12. Range of Neck Movement
- Extension _____
- L Lat. flex _____
- R Lat. Flex _____

13. Trunk height in corrected sitting _____
14. Trunk height in resting sitting _____
15. Vertical Distance from LEMD
- a. helix _____
- b. C₇ _____

16. Horizontal Distance from LEMD
- a. helix _____
- b. C₇ _____

ANGLES
helix
C ₇

APPENDIX THREE

Headache data

Table of Contents

Part 1	Headache frequency	XXXI
Part 2	Stiff and Aching Necks	XXXIII
Part 3	Headache management	XXXV
Part 4	Neck X-ray	XXXVII
Part 5	Posture and Pain	XXXVIII
Part 6	Functional Activities	XXXIX

Part 1. Headache frequency

The headache frequency data were divided into gender and age groups in the broad headache categories of none, occasional (occ H/A) and frequent (freq H/A). The raw data is reported in Tables 1Ci and 1Cii. Proportions calculated from this data are reported in Tables 2Ci and 2Cii.

Table 1Ci. Gender specific headache categories

	Female			Male		
	headache categories			headache categories		
	none	occ.	freq.	none	occ.	freq.
N	59	83	69	96	68	52
Total N	211			216		
% total	27.9%	39.3%	32.7%	44.4%	31.5%	24.1%

Table 1Cii. The number of subjects in age group/ gender-specific headache categories

Women	no H/A	occ. H/A	freq. H/A	<i>row Total</i>
Age group				
< 40 years	29	41	29	99
40-59 years	16	30	30	76
60+ years	14	12	10	36
<i>column Total</i>	59	83	69	211

Men	no H/A	occ H/A	freq H/A	<i>row Total</i>
Age group				
40-59 years	37	38	24	24
60+ years	11	5	7	23
<i>column Total</i>	96	68	52	216

Table 2Ci. Proportion of study sample (and 95% Confidence Limits) in each headache (H/A) category

	total group (95%CL)	females (95%CL)	males (95%CL)
no H/A	36.3% (32.8%, 40.8%)	27.9% (21.9%, 33.9%)	44.4% (37.6%, 50.6%)
occ. H/A	35.4% (27.8%, 43%)	39.3% (32.7%, 45.9%)	31.5% (28.3%, 34.7%)
freq. H/A	28.3% (24%, 32.7%)	32.7% (26.4%, 39%)	24.1% (18.4%, 29.8%)

Table 2Cii. Prevalence of headache in the broad age categories.

	occ. H/A (95%CL)	freq. H/A (95%CL)	Total
young (18-39 years)	34.2% (40.9%, 27.7%)	25.9% (19.8%, 34.6%)	193
middle (40-59 years)	38.8% (32.1%, 44.7%)	30.8% (21.8%, 39.8%)	175
old (60+ years)	28.8% (23.5%, 34.1%)	28.8% (24.7%, 32.9%)	59

Part 2: Stiff and Aching necks

The subjects reporting stiff and aching necks were divided into the three broad headache categories. The raw data is reported in Table 3C. The observed and expected odds of reporting stiff and aching necks are illustrated in Figure 1C.

Table 3C. Frequency of stiff and/or aching neck, reported as a percentage of total subjects in each headache group

	no H/A	occ. H/A	freq. H/A
no stiff or aching neck	133	57	19
reports of stiff neck only	4 (2.6%)	11 (7.3%)	5 (4.1%)
reports of aching neck only	13 (8.4%)	41 (27.1%)	29 (23.9%)
reports of both stiff and aching necks	5 (3.2%)	42 (27.8%)	68 (56.2%)
Total	155	151	121

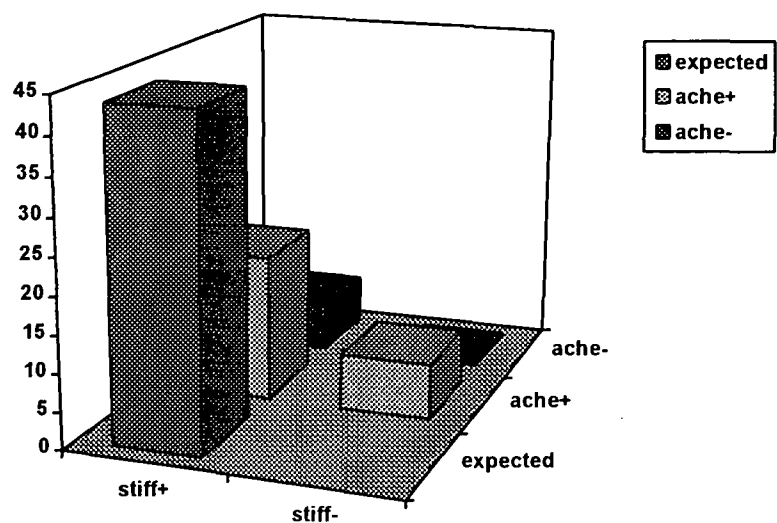


Figure 1Ci. Observed and expected odds of stiff and/or aching necks occurring in subjects with occasional headaches, when compared with the odds for subjects with no headache.

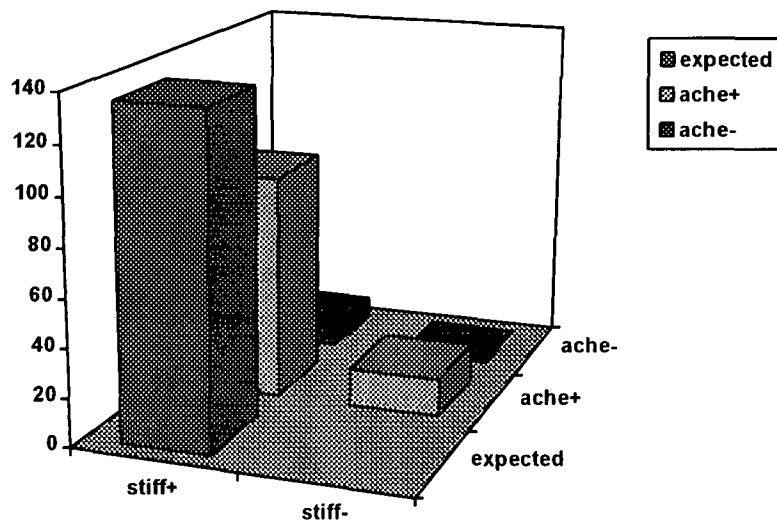


Figure 1Cii. The observed and expected odds of stiff and aching necks occurring in subjects with frequent headaches.

Part 3. Headache management

Subjects were provided with a number of questionnaire choices regarding the way in which headache pain was managed. These categories were combined *a priori* on the basis of the ease of obtaining pain relief. The raw data is provided in Table 4Ci. The most frequently reported methods of pain relief were ranked in descending order in Table 4Cii.

Table 4Ci. Frequency of reporting of pain management methods

NB M = Medication

	% occ. H/A	% freq. H/A
no management	33 (21.8%)	20 (16.5%)
rest	31 (20.5%)	25 (20.7%)
heat, cold, etc	12 (7.9%)	6 (4.9%)
simple M.	61 (40.4%)	53 (43.8%)
complex M.	14 (9.3%)	17 (14.1%)
Total	151	121

Table 4Cii. Ranked, grouped pain relief measures for headache

NB M=Medication

Ranking	occ. H/A	freq. H/A			
		2 per month	4 per month	15 per month	30 per mont
1.	simple M.	simple M.	simple M.	simple M.	simple M.
2.	passive	rest	rest	complex M	rest
3.	complex M.	no managemt	no managemt	no managemt	complex M.
4.	no managemt.	complex M.	complex M.	rest	
5.	heat / cold	heat / cold	heat / cold	heat / cold	

Part 4. Neck X-ray

Subjects reported the reasons for radiological investigation of the neck. The relevant data are reported in Table 5C.

Table 5C. Reasons for X-ray of the neck

Reason for X-ray	no H/A	occ. H/A	freq. H/A
neck pain	6	16	24
shoulder pain	4	5	10
carpal tunnel	1	5	4
headache	0	2	2
Scheuermans' Disease	0	1	1
Thyroid problems	1	2	3
Insurance purposes	0	2	2
Group Total	12	33	46
Overall Total	155	151	121

Part 5. Posture and headache

This section reports on the frequency with which headache occurred in five divisions of the excursion angles. The headache data were treated ordinally. While a significant mean difference in headache frequency was noted across the divisions of the C₇ variable ($F = 6.57, p=0.01$), no similar difference was observed for the helix variable ($F=0.86, p>0.05$). *T*-tests between consecutive pairs of the C₇ data divisions identified that significant differences in mean headache frequency occurred between the fourth and fifth data divisions (i.e. at 11.5 degrees excursion). The results of testing are provided in Table 6C and graphed in Figure 2C.

Table 6C. Variation in headache frequency across excursion angle divisions

	C ₇ angles		helix angles
	mean H/A (S.D.)	<i>t</i> -test (<i>p</i> value)	mean H/A (S.D.)
division 1	2.47 (1.63)		2.44 (1.68)
division 2	2.32 (1.64)	0.55 (0.57)	2.25 (1.54)
division 3	2.69 (1.76)	-1.42 (0.15)	2.25 (1.67)
division 4	2.41 (1.65)	1.17 (0.24)	2.67 (1.67)
division 5	3.05 (1.84)	-2.55 (0.01)	2.64 (1.67)

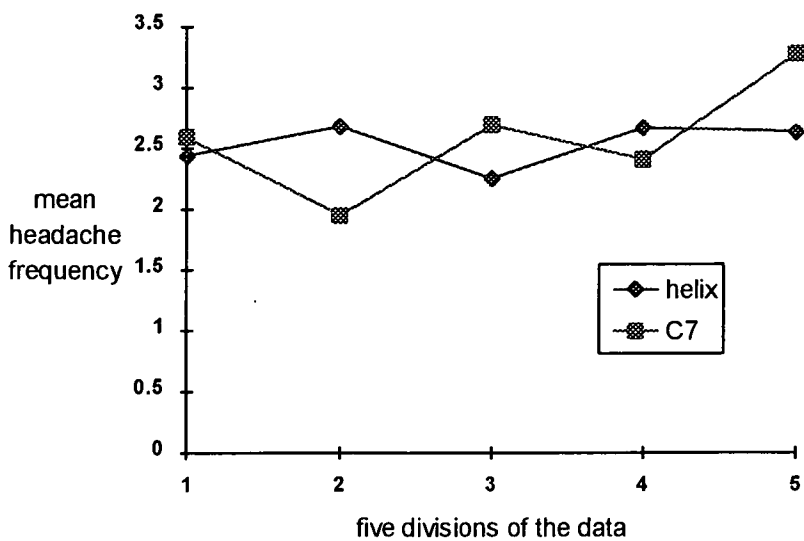


Figure 2C. Mean headache frequency in divisions of excursion angles

Part 6. Functional activities associated with headaches

The functional activities were grouped according to similar biomechanical function. These events are reported in their biomechanical groupings in Table 7Ci. The frequency with which these events were reported is listed in Table 7Cii. The grouped events are reported in descending order in Table 7Ciii. The frequency with which headache subjects with at-risk excursion angles report these events is provided in Table 7Civ.

Table 7Ci. Grouped events associated with the onset of headache

neck extension	static neck flexion	static head held straight	jarring / rotation	lifting	stress
hanging out the washing pruning trees	sharpening saws vacuuming	computing playing piano	chain sawing driving a tractor	repeated lifting	running late overtired
painting ceilings	playing guitar	typing	wearing a seat belt		stress or pressure at work
reaching up	gardening	sitting for long periods	chopping wood		
cleaning walls	sewing	prolonged driving			
stacking boxes	sitting at a desk writing				
cleaning windows	knitting				

Table 7Cii. Frequency of reporting of events that precipitate headache

events	no. occ. H/A (% total occ. H/A)	no. freq. H/A (% total freq. H/A)
neck extension	22 (14.5%)	21 (17%)
neck flexion	15 (9%)	16 (13%)
static sitting	15 (9%)	10 (8%)
jarring / rotation	5 (3%)	3 (2.5%)
lifting	3 (2%)	9 (7%)
stress	0 (0%)	6 (5%)
unknown	91 (60%)	56 (46%)
Total N	151	121

Table 7Ciii. Ranked events that precipitate headache

Ranking	occ. H/A	freq. H/A
1.	neck extension	neck extension
2.	active neck flexion	active neck flexion
3.	static sitting	static sitting
4.	jarring/ rotation	lifting
5.	lifting	jarring / rotation
6.	stress	stress

Table 7Civ. Frequency of reporting by subjects with at-risk excursion angles

	with at-risk helix		with at-risk C ₇	
	occ. H/A	freq. H/A	occ. H/A	freq. H/A
Activity				
1. extension	16%	15%	15%	15%
2. static neck posture	7%	13%	4%	10%
3. active neck flexion	15%	8%	11%	8%
4. lifting	4%	2%	0%	0%
5. jarring / rotation	3%	7%	4%	8%
6. stress	0%	6%	0%	8%
7. unknown	55%	49%	66%	51%

APPENDIX FOUR

Papers published from this study

Contents

1. Grimmer K (1993): The association between occupational status and cervical origin headaches *American Journal of Occupational Medicine* 35: 929-935.
2. Grimmer K (1993): Measurement of Cervical Resting Posture in a Treatment Setting *Physiotherapy* 79: 451-455.
3. Grimmer K (1994): Measuring the endurance capacity of the cervical short flexor muscle group. *Australian Journal of Physiotherapy* 40: 251-251.
4. Grimmer K (1996): Cervical resting posture and pain. *Physiotherapy* 82: 45-51.

The Relationship Between Cervical Resting Posture and Neck Pain

Karen Grimmer

Key Words

Cervical excursion angles, cervical resting posture, neck pain, never-injured subjects.

Summary

The excursion of two anatomical landmarks on the cervical spine was measured as never-injured subjects moved from a standard sitting position to their habitual cervical resting posture in sitting. The angular excursion traced by these two anatomical points was considered simultaneously in order to describe individual resting postures. The data for neither excursion angle approximated the normal distribution. Subjects with extreme cervical excursion were thus identified by dividing the data into five groups, and designating the first and last groups as extremes of the population range. Four groups of subjects with extreme angles of excursion occurring at both anatomical points were identified and photographed, and the differences in their postures discussed.

Subjects' reports of neck pain which had occurred in the preceding month were employed in order to test the hypothesis that more subjects with extreme cervical resting posture reported neck pain than did subjects whose cervical posture more closely approximated the population average. No association was evident, and the hypothesis was thus rejected. Suggestions are made for further investigation of both the hypothesis and the existing data.

Introduction

Normal resting head posture has been described when the line of gravity passes through the external auditory meatus, posterior to the coronal suture, and through the odontoid process (Kendall *et al*, 1952). This is believed to be the most efficient of all resting head postures (Saunders, 1985; Wagenhausen, 1971), because minimum energy is expended to counterbalance the head against gravity (Abrahams, 1977; de Vries, 1966; Dunsker *et al*, 1978; Turner, 1956). A wide variation in habitual resting head postures in normal subjects has been observed radiologically (Fineman *et al*, 1963; Gore *et al*, 1986; Juhl *et al*, 1962; Penning, 1978). There is little evidence that extreme cervical resting postures are more strongly associated with pain than are cervical resting postures which more closely approximate to the population norm.

Nevertheless, postures which are perceived to

vary markedly from the 'norm' have traditionally been corrected by physiotherapists on the understanding that they are associated with increased biomechanical stresses and pain (Trott, 1988). There is little objective evidence upon which to base these perceptions, as few population-based studies have been undertaken to assess the relationship between resting posture and pain. Physiotherapists in clinical practice cannot now measure objectively an individual's cervical resting posture, or assess an individual's posture with respect to the range of resting postures found within the population, because of the lack of a standard, reliable, efficient and inexpensive method of measuring posture.

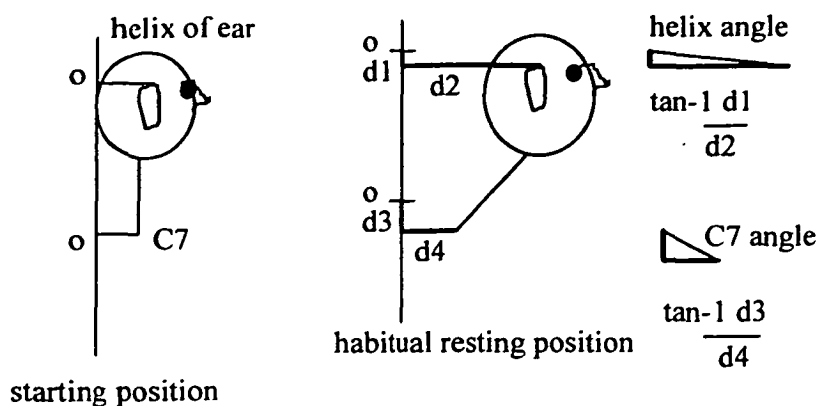
This paper seeks first to describe the range of cervical excursion inherent in the resting head postures of a randomly selected sample of never-injured subjects, and then secondly to test the hypothesis that more subjects with extreme cervical resting posture report neck pain than do subjects whose cervical resting posture more closely approximates to the population mean.

Method

Measurement of Cervical Resting Posture

The linear excursion movement device (LEMD) was developed for use in clinical settings to provide measurements which were considered by the author to represent cervical resting posture. The device measures the excursion (Hanten *et al*, 1991) (horizontally and vertically) of two anatomical landmarks when seated subjects move into their habitual resting cervical posture from a standard position. The anatomical landmarks chosen for measurement using the LEMD were the superior-most tip of the helix of the ear and the spinous process of C7. Both these points were readily identifiable, and were considered by the author to represent the upper and lower aspects respectively of the cervical spine. A pilot study established that measurements from the device were highly reproducible over consecutive days (Grimmer, 1993). This study reported that the r^2 values obtained from comparing consecutive measurements were greater than 0.80, and p values greater than 0.05 were obtained from t -tests for correlated means.

Fig 1: Use of the linear excursion measuring device



The LEMD was positioned on an adjustable plinth so that subjects could sit with their feet flat on the floor, with thighs, knees and ankles at 90°. Forearms rested comfortably on thighs. Subjects spotted a letter on a wall chart which hung in front of them, and maximally retracted their chins as described by McKenzie (1983). The position of the superior-most tip of the helix of the ear and the spinous process of C7 were marked on vertical rulers. Subjects then assumed their usual resting posture using the natural head posture technique described by Solow and Tallgren (1971). During this procedure, subjects maintained the contact between their scapulae and the backboard, and spotted the selected letter during each head sweep. Once habitual resting posture was achieved, the new position of the superior-most tip of the helix of the ear and the spinous process of C7 were marked, and the vertical and horizontal distances through which these points had travelled were recorded.

These linear measurements were then converted to angles using the formula:

$$\tan^{-1} \frac{\text{vertical distance travelled}}{\text{horizontal distance travelled}}$$

The process of measurement is illustrated in figure 1.

Subjects

A total of 450 individuals were randomly chosen from the electoral rolls of two adjacent southern municipalities of Tasmania, Australia, during 1990-1992. Of these selected individuals, nine chose not to participate, and 14 were excluded on the grounds that previous injury to the neck, currently taking anti-inflammatory medication or analgesia, pregnancy and/or breast feeding, had the potential to affect habitual resting posture of the head. Thus, 427 subjects provided one set of measurements. In order to determine the reproducibility of the measurements, the first 100 were also requested to return one calendar month after the initial measurement session to provide a second set of measurements.

Measurements

At the first measurement session (attended by all 427 subjects), measurements of the excursion of the superior-most tip of the helix of the ear and the spinous process of C7 were taken by the one investigator using the LEMD. At this measurement session all subjects were requested to report on any episodes of neck pain suffered in the preceding month. The investigator remained unaware of the subjects' pain status during the measurement period.

For the calendar month following the initial measurement session, the first 100 of the 427 subjects were requested to maintain a pain diary on which all episodes of neck pain were recorded. These subjects handed in their pain diary on their return at the end of the month, when they provided the second set of the posture measurements.

The first and second posture measurements were compared, as were the retrospective and prospective reports of neck pain in order to determine the reproducibility of the measurements.

Determining Extreme Excursion Angles

Three separate steps were undertaken in order to identify subjects who demonstrated extreme excursion angles at both the superior-most tip of the helix of the ear as well as at the spinous process of C7. The data on all 427 subjects were employed in this analysis, following assurances of the reproducibility of the measurements of excursion and neck pain in consecutive months.

- The association between the angular excursion of the superior-most tip of the helix of the ear and spinous process of C7 was examined in the first instance in order to detect any trends in the data.

- The frequency distributions of the excursion angle data from each anatomical point were examined for the purpose of determining extreme angles within the range of the population. The degree of approximation to the normal distribution of the frequency distributions, estimated by the Shapiro-Wilk statistic, dictated the manner in which extreme angles were identified.

- The data from both excursion angles were then combined in order to provide a description of the resting posture of every subject, that is, it was considered by the author that an individual's resting posture was described by the amount of excursion occurring at the superior-most tip of the helix of the ear as well as that occurring at the spinous process of C7. Those subjects with extreme excursion occurring at both anatomical points were identified during this step, and were recalled and photographed in their usual seated cervical resting posture for record purposes.

Prevalence of Neck Pain

The prevalence of neck pain was established using the data provided by all 427 subjects. A multiple ANOVA procedure was conducted in order to test whether significantly more subjects

with extreme cervical resting posture reported neck pain than did subjects with cervical resting posture which more closely approximated to the population mean.

Results

Reproducibility of Measurements

This section reports on the comparison between the first and second set of measurements which were requested from the first 100 of the 427 subjects. Two sets of measurements were available on only 93 of these 100 subjects, as seven subjects did not return for the second measurement session. The comparison of the first and second posture measurements provided high Pearson correlation coefficients which indicated that the excursion measure was stable (Nunnally, 1972). For the spinous process of C7, the r^2 statistic was 0.78, and for the superior-most tip of the helix of the ear, the r^2 statistic was 0.80. Intraclass correlation coefficients (ICC) with random subject effects indicated that there was also a high level of agreement between the first and second posture measurements (Armstrong *et al*, 1992). The ICC for the spinous process of C7 was 0.87, and the ICC for the superior-most tip of the helix of the ear was 0.88. As these findings supported those of the pilot study (Grimmer, 1993), it was concluded that the measure of cervical excursion was reproducible both over consecutive days and a month.

A comparison of retrospective and prospective reports of neck pain indicated that this measure was also stable and that the measurements were in good agreement. The Spearman correlation coefficient was 0.64 (SE 0.10). Neck pain was recorded prospectively by 91.4% of the individuals who reported it retrospectively. The kappa statistic, which demonstrated agreement beyond chance for events of neck pain occurring in consecutive months (Richman *et al*, 1980) was moderate (0.62; SE 0.08), and there were significant odds that neck pain would be reported in both months of testing (odds ratio = 21.3; 95% CL 5.8 – 78.7). As a result of this testing, the author was confident that the measurements on all 427 subjects provided accurate descriptions of cervical excursion and neck pain.

Extreme Excursion Angles

In determining extreme excursion angles in the data on the 427 subjects, poor association was observed between the excursion of the superior-most tip of the helix of the ear and the spinous process of C7 ($r^2 = 0.04$). This finding illustrated the wide variability in the excursion of the

anatomical landmarks on the upper and lower aspects of the cervical spine which was found in this sample of subjects. Thus there were no obvious trends in the relative angular excursion of the upper and lower aspects of the cervical spine during the assumption of habitual cervical resting posture in sitting.

Left skewed frequency distributions were observed in the excursion angle data for both anatomical landmarks. Neither set of data approximated the normal distribution, as in both cases the Shapiro-Wilk statistic was significantly different from the value of one (0.93; $p = 0.0001$) for the spinous process of C7 and 0.92 ($p = 0.0001$) for the superior-most tip of the helix of the ear.

- The population range of the angular excursion of the superior-most tip of the helix of the ear was from 1° to 18° , with a mean value of 5.7° (interquartile range 3° to 7°).

- The population range of the angular excursion of the spinous process of C7 was from 1° to 25° , with a mean value of 8.1° (interquartile range 5° to 11°).

Extreme angles were identified by dividing the data into five relatively equal parts. This approach has been suggested by Cramer (1991) and Rothman (1986) as a method of identifying patterns of risk in an abnormally distributed exposure variable. The data divisions for each excursion angle are reported in table 1.

Subjects with excursion angles falling in the first data division for the superior-most tip of

the helix of the ear and the spinous process of C7 were considered to have extremely small cervical excursion. This identified all those subjects with:

- 2.5° or less at the superior-most tip of the helix of the ear; or

- 4° or less excursion at the spinous process of C7.

Subjects with excursion angles falling in the fifth data division were considered to have extremely large cervical excursion. This identified all those subjects with:

- 8.5° or more excursion at the superior-most tip of the helix of the ear; or

- 11.5° or more excursion at the spinous process of C7.

The excursion angle data were combined in order to provide what the author considered to be an illustration of individual habitual resting posture. Twenty-five different presentations of cervical resting posture were identified by cross-tabulating the five data divisions for each excursion angle. The cross-tabulation of the data is reported in table 2. From this table it can be observed that four groups of subjects had extreme excursion occurring at both anatomical points.

- Extremely small excursion angles occurring at both the superior-most tip of the helix of the ear and the spinous process of C7 were demonstrated by 13 subjects.

Table 1: Five divisions in the excursion angle data (n = the number of subjects in each of the five data divisions)

Data division into quintiles	Spinous process of C7			Superior-most tip of the helix of the ear		
	Angles associated with each quintile	Cumulative percentage in the data	No	Angles associated with each quintile	Cumulative percentage in the data	No
1	1. -4	22.7	97	1 - 2.5	17.3	74
2	4.1-6	42.4	84	2.6- 4.0	40.3	98
3	6.1-8	59.7	74	4.1- 5.5	54.8	67
4	8.1-11.4	78.2	79	5.6- 8.4	80.3	109
5	11.5-25	100	93	8.5-18	100	79

Table 2: Prevalence of neck pain in each of the 25 postural groups

Helix angles	Quintile divisions (%)				
	1 (1° - 2.5°)	2 (2.6° - 4°)	3 (4.1° - 5.5°)	4 (5.6° - 8.4°)	5 ($> 8.5^\circ$)
<i>C7 angles</i>					
1. (1° - 4°)	33.3 (n = 21)	54.2 (n = 24)	40 (n = 15)	60.1 (n = 23)	42.8 (n = 14)
2. (4.1° - 6°)	31.5 (n = 19)	38.2 (n = 13)	50 (n = 16)	55 (n = 20)	56.2 (n = 16)
3. (6.1° - 8°)	46.1 (n = 13)	65 (n = 20)	80 (n = 5)	7.7 (n = 26)	30 (n = 10)
4. (8.1° - 11.4°)	75 (n = 8)	34.6 (n = 26)	58.8 (n = 17)	47 (n = 17)	36.4 (n = 11)
5. ($> 11.5^\circ$)	46.6 (n = 15)	46.7 (n = 15)	55.5 (n = 9)	53.6 (n = 28)	50 (n = 28)
Total					46.4 (n = 427)

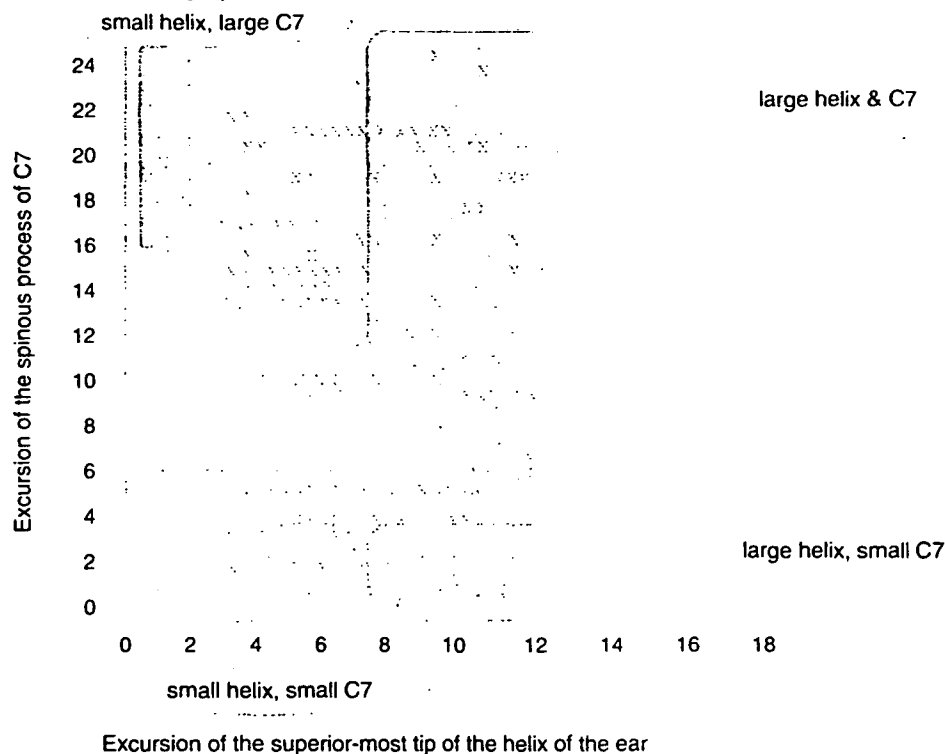


Fig 2: Raw excursion angle data and the extreme posture groups within the data

- Extremely large excursion angles occurring at both the superior-most tip of the helix of the ear and the spinous process of C7 were demonstrated by 23 subjects.
- An extremely small angle at the superior-most tip of the helix of the ear and an extremely large angle at the spinous process of C7 excursion were demonstrated by ten subjects.
- An extremely large angle at the superior-most tip of the helix of the ear and an extremely small angle at the spinous process of C7 excursion were demonstrated by 11 subjects.

The raw excursion angle data and the extreme groups falling within the data are illustrated in figure 2.

An examination of photographs taken of those subjects with two extreme angles of excursion highlighted large differences in resting head postures in this never-injured population. On one hand it was observed that subjects with two extremely small angles of excursion held their heads well forward of the vertical axis on a protracted lower cervical spine. On the other hand, subjects with two extremely large angles of excursion held their heads just anterior to the vertical axis on an extended lower cervical spine (fig 3).



Fig 3: Extremely small excursion angles at Helix and C7



Fig 4: Extremely large excursion angles at both helix and C7

Occurrence of Neck Pain

Of the 427 subjects in this study, 46.7% reported neck pain in the previous month. The prevalence of neck pain varied within the 25 posture groups, with extremes of 7.7% prevalence (found in cell 3,4) and 80% prevalence (in cell 4,4). The number of subjects falling in each of the 25 posture groups, and the prevalence of neck pain in each group are shown in table 2. Despite the wide variation in the prevalence of neck pain, a multiple ANOVA provided no evidence of significant differences in the prevalence of neck pain occurring across the 25 groups ($F = 0.80$, $p = 0.37$).

Discussion

By measuring the excursion of selected anatomical points on the head and neck as the head moves from a standard corrected position to its habitual resting posture (Hanten *et al*, 1991), the clinician is encouraged to focus on the essence of postural correction. While it is yet to be demonstrated that the cervical excursion measurements described in this paper provide an adequate and appropriated description of individual cervical resting posture, the author considers that the concept of excursion provides a useful measure of the amount of correction which is necessary to approximate an individual's head position with the gravitational axis. The concept of cervical excursion offers clinicians an efficient, accurate, standardised approach to measurement which can be employed to describe an individual's posture with respect to the range found in the population. Such comparison is useful, particularly when dealing with patients' and referrers' expectations. It was of interest to the author that the population average tended towards small angles of excursion at both the upper and lower cervical spine. These angles of excursion described the average resting head posture in never-injured individuals as one where the head was held forward of the gravitational axis on a protracted lower cervical spine.

At least one event of neck pain occurred in both months of testing for approximately 91% of these never-injured subjects. The random nature of the subject selection, the high compliance rate and the demonstrated reproducibility of the results suggested that these findings adequately reflect the occurrence of neck pain in never-injured individuals. As the treatment of neck pain is one area on which physiotherapists concentrate, the reasons for such consistent occurrence of neck pain require further investigation.

The lack of obvious association between events of neck pain and cervical excursion angles supports the rejection of the hypothesis that more never-injured subjects with extreme cervical excursion report neck pain than never-injured subjects with average cervical excursion. This finding, however, should not dampen enthusiasm for further investigation, as the author was concerned about several issues which may have led to the erroneous rejection of the hypothesis. For example, in order to provide information on a large sample of randomly selected subjects, retrospective data collection was considered to be the most cost and time efficient method. While it was demonstrated that the neck pain measurements were reproducible

when compared with prospective reports, the occurrence of neck pain in never-injured individuals needs to be examined more closely in order to minimise potential misclassification.

An advantage in future investigations would be the collection of additional data, such as the number of events of neck pain occurring over several months, the activities which precipitated the neck pain and the number and location of tender spots on the neck occurring in conjunction with the events of neck pain. These data may well help in confirming local structures in the neck as sources of pain as well as identifying the postural stresses associated with pain. Information on potential confounding factors would also help when controlling for important influences on the association between cervical excursion and pain. Factors which have been suggested as causal agents for neck pain, and which may well act as confounders or modifiers in this causal model are the patient's occupation, body build, age, and neck muscle performance (Hagberg and Wegman, 1987; Hult, 1954; Salminen, 1984).

The relationship between cervical excursion and neck pain in never-injured subjects also needs to be examined more closely than by the process which was described for this paper. For instance, in this paper both angles of excursion were examined simultaneously. Further investigation of the data should be undertaken using only one set of excursion angle data at a time, and controlling for the confounding and/or modifying influences of the excursion occurring at the other anatomical point, in the event that one set of excursion angles obscured the true nature of the association between pain and the other set of excursion angles.

The relationship between the excursion of the two anatomical points also requires closer examination. In this paper, the lack of visual evidence of a relationship between the excursion angles was described, and a strong linear association between the excursion angles was rejected on a lack of evidence. More sophisticated mathematical modelling of the data may be indicated, particularly in the light of the recent work conducted by Refshauge *et al* (1994), where a third-order polynomial equation was employed to express the association between two measurements of the resting position of the cervical spine. If a stronger association between the two excursion angles could be detected in such a way, an association between posture and pain might become more obvious.

Conclusion

This project provided two pieces of information that are of use to clinicians, these being:

- the amount of cervical excursion in sitting varies little over a month for never-injured individuals; and
- description of the population range for never-injured individuals of the excursion of two standardly anatomical points.

Thus it can be suggested that a never-injured individual's posture measured on any one day is a reasonable approximation to his/her posture measured on any other day within the same month. The illustration of the population range of cervical excursion facilitates comparisons of a never-injured patient's head position with respect to the population norm.

This study found that the occurrence of neck pain in never-injured individuals is not dependent on the amount of cervical excursion. It thus appears that extreme cervical excursion occurring at both aspects of the upper and lower cervical spine is not a causal agent of neck pain. However, the findings of this study need to be further tested in order to take account of the sources for potential error.

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Measuring the endurance capacity of the cervical short flexor muscle group

Karen Grimmer

The role of the cervical short flexor muscles in maintaining head posture has been recognised recently. While a computerised device is available for measuring isometric performance of this muscle group, no clinical method is available. This paper reports on an inexpensive and time-efficient method of measuring the endurance capacity of the cervical short flexor muscle group in a clinical setting. The measurement is adapted from an exercise described and illustrated by Trott (1988). The measurements of cervical short flexor endurance were reproducible over a one month interval. There was a systematic improvement in mean endurance capacity for both women and men and the possible causes of this are discussed. (Grimmer K: Measuring the endurance capacity of the cervical short flexor muscle group. *Australian Journal of Physiotherapy* 40: 251-254)

Key words: Neck Muscles; Posture; Reproducibility of Results

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The cervical short flexor muscle group is believed to play an important role in stabilising the position of the head on the neck (Fulton 1989, Janda 1988, Richardson 1989, Trott 1988). Evidence to support this activity was provided recently by reports of an intense network of nerve fibres surrounding the cervical short flexor muscles which probably serve a proprioceptive function (Gurumoorthy 1991). The muscles comprising the cervical short flexor group are rectus capitis anterior and lateralis, and longus capitis and colli (Basmajian 1980, Moore 1985). While poor isometric performance of the cervical short flexor muscles has been observed in females with chronic cervical origin headache and forward resting head posture (Watson and Trott 1991), the nature of this association has not been established.

A computerised device has been developed by Watson and Trott (1991) to measure the isometric performance of the cervical short flexor muscle group. Despite its potential, the device has not filled the need to measure the performance of the cervical short flexor muscle group in clinical settings because of its high cost and general lack of availability. This paper proposes a method of measuring cervical short flexor muscle endurance in a clinical setting with the objective of encouraging more physiotherapists to measure and record their observations. The method is based on an exercise for educating anti-gravity

function of the cervical short flexor muscle group (Trott 1988). This is a gravity-resisted exercise where the chin is "tucked (upper cervical flexion) while just taking the weight of the head off the pillow" (p. 236-237). It is proposed that the length of time during which a subject maintains Trott's (1988) anti-gravity head position measures cervical short flexor muscle endurance.

This paper reports on the reproducibility of the proposed measure of cervical short flexor endurance. The results presented in this paper were generated from a larger study which received ethics committee approval from the University of Tasmania.

Method

In the exercise protocol described by Trott (1988), subjects lay supine on a plinth, retracted their chin and lifted their head a short distance from a pillow placed under the head. The proposed method of measuring cervical short flexor muscle endurance refined Trott's (1988) protocol in three ways:

- (1) No pillow was used.
- (2) A distance of 2cm from the back of the head to the plinth was arbitrarily chosen to standardise the lift from the plinth. The 2cm lift was confirmed visually by the examiner, using a vertical ruler placed at the side of the plinth. Since head weight differs from subject to subject, the same

From Page 251

amount of head lift on test and retest ensured the same load was placed on individual cervical short flexor muscles. The test position is illustrated in Figure 1.

- (3) The time between assuming the test position until the chin began to thrust was measured in seconds with a stop watch. Chin thrust was determined in two ways: by light finger pressure over the point of the subject's chin, and by observation.

Subjects

One hundred and five subjects were selected randomly from the electoral roll of a southern Tasmania municipality. Access to the electoral roll was gained on the basis of the approved nature of the study. Five subjects were excluded on the grounds that injury to the neck affects cervical short flexor muscle endurance, and known degenerative conditions of the neck cause joint abnormalities which can impede the normal performance of the deep flexor muscles of the neck (Gurumoorthy 1991). The remaining 100 subjects agreed to participate in the study. The reason for the study was explained to them and they signed a standard consent form. Following the initial measurement, the subjects were asked to return one calendar month later for re-measurement, and 93 did so (38 women and 55 men).

Test procedure

The same test for cervical short flexor endurance was applied at both measurement sessions. The test and retest results were recorded on separate sheets, and no feedback was given to the subjects or the examiner regarding the results of either test. The subjects were not allowed to practise before the test measurement was taken, however they were not asked to refrain from practising the test during the next month.

Analysis

Statistical analysis was conducted using SAS Release 6.03 (SAS/STAT Users

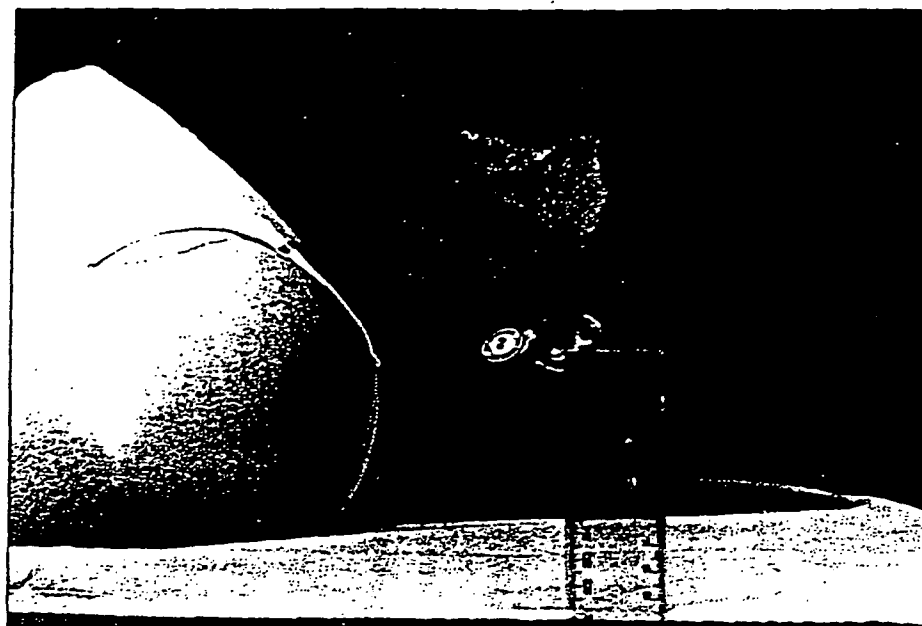


Figure 1.
The test position.

Guide Release 6.03 1988, Schlottzauer and Littell 1987). To establish the influence of gender on cervical short flexor endurance, *t* tests were conducted using the initial test measures. These *t* tests were conducted under an hypothesis of unequal variance because of the unequal numbers of males and females in the sample.

The stability of the proposed measure was evaluated by determining the association between the test and retest scores reported as the square of the Pearson product moment correlation statistic (r^2). This statistic has been defined as "the proportion of the total variation in one set of scores that can be explained by the other set" (Maher 1993 p. 6). A high level of association between the scores indicated that the same characteristic had been measured on both occasions of testing. The level of agreement between scores was investigated in three ways. Intraclass correlations and the percentage contribution of the within-subject variation to the total variation between scores were calculated from the output of an analysis of variance procedure using a random effects General Linear Model (Armstrong et al 1992).

The difference between test and retest means was investigated using *t* tests for correlated means (reported in Runyon and Haber (1972) p. 205). This analysis was employed because the same test had been applied to the same subjects on two occasions. Correlated errors were anticipated and the occurrence of significant differences between means was considered to provide evidence of systematic changes affecting the scores on retest (Altman and Bland 1983).

Results

Gender differences

The female subjects had significantly poorer cervical short flexor endurance than the male subjects ($t_{(1)} = -4.53, p = 0.0001$). That is, the women were able to maintain the required position for a period of time which was significantly less than that recorded by the men. Women had a mean endurance capacity of 14.5 seconds (SD 4.3). The mean endurance capacity for men was 18.2 seconds (SD 3.3). On the basis of these results, men and women were investigated separately in subsequent analyses.

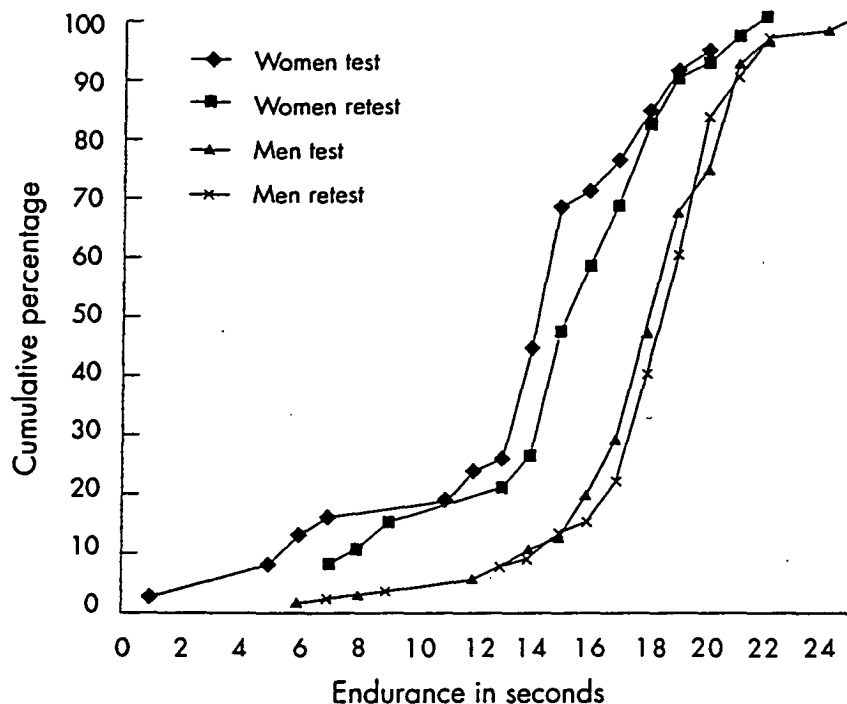


Figure 2.
The gender-specific population range for test and retest presented as cumulative frequencies.

Level of association

High levels of association between the test and retest results were found for both men and women (women $r^2 = 0.86$, $p = 0.0001$; men $r^2 = 0.88$, $p = 0.0001$). That is, the measures recorded on each occasion were highly related and supported the fact that the characteristic being measured was extremely stable over time.

Level of agreement

The intraclass correlations were high for both men and women. The intraclass correlation for women was 0.92 (lower 95 per cent confidence limit 0.82), and for men 0.93 (lower 95 per cent confidence limit 0.89). Richman et al (1980) indicates that good agreement between scores occurs at correlations above 0.80. The individual subject variation from one test to the next was similarly small for men and women with the within-subject variation contributing 4.2 per cent to the total variation between tests

for women and 3.1 per cent to the total variation between tests for men. These results indicated that the test measured the same characteristic on both occasions of testing and restricted within-subject variability to less than 5 per cent for both men and women on the second test.

Systematic changes to the test and retest means occurred for both men and women. On the second test, a mean improvement of 1.2 seconds (upper 95 per cent confidence limit = 1.7 seconds) occurred for women and a mean improvement of 0.27 seconds (upper 95 per cent confidence limit = 0.56 seconds) occurred for men. This improvement was significant for women ($t_{(11)} = -4.5$, $p = 0.0001$), and approached significance for men ($t_{(11)} = -1.82$, $p = 0.07$). The population range of the test and retest measurements was graphed as a cumulative percentage and is shown in Figure 2 for both men and women to illustrate the gender

and test differences.

Discussion

The proposed measure of cervical short flexor muscle endurance provided reproducible measurements on two occasions of testing one month apart. The characteristic of the measure was stable and there was good agreement between individual scores. The validity of the proposed measure was not the subject of the present examination and remains to be established. However, as the measure was based on an exercise which was reported to improve the isometric performance of the cervical short flexor muscle group (Trott 1988), the proposed measure was assumed to have face, construct and content validity (Payton 1988). In the absence of a true measure of cervical short flexor endurance, the validity of the proposed measure could be determined on a subsequent occasion by comparing the present results with those generated by the computerised device described by Watson and Trott (1991).

Men demonstrated significantly greater endurance capacity than women. As no gender effect was noted in the stability of the characteristic, or in individual variability between test and retest scores, the proposed test of cervical flexor endurance capacity appeared to work equally well for men and women. A systematic improvement in retest scores was observed for both men and women, with the mean improvement being greater for women than for men. Given the reproducibility of the test, this improvement can be attributed to three factors:

- (1) The systematic change may have resulted from measurer error. To time the test, monitor the head lift and establish the moment when chin thrust occurred demanded a high level of concentration and might have been better managed by two individuals. The ability of the measurer and/or the skill needed to detect the moment of chin thrust might have improved

From Page 253

with practice, leading to the change noted over time.

- (2) Since the subjects were not given any instruction not to practise the flexor exercise between test occasions, some might have practised the test during the one month interval between testing, resulting in an improvement in performance on the retest session.
- (3) The systematic change may have resulted because subjects had a better understanding of the test procedure on the second occasion of testing. However, the proposed method of measuring cervical short flexor endurance was adapted from an exercise to improve isometric capacity. The proprioceptive function of the cervical short flexor muscles has been noted. The method of measuring cervical short flexor endurance might have provided sufficient proprioceptive input to improve the performance of the muscle group on the second test. Nevertheless, this explanation of the improved performance appears the least likely.

Observation of the cumulative frequency graph suggested that the systematic improvement was critically related to endurance capacity. Subjects with poor endurance capacity demonstrated greater changes on retest than subjects with better endurance capacity. Women had significantly poorer endurance capacity than men. While all subjects with poorer endurance capacity might have gained a treatment benefit from participating in this study, it is possible that the women practised more than the men between testing occasions. These findings should be further tested on a larger population with measurements made over several different time intervals. It would also be useful to provide more specific instructions for the test protocol.

Conclusion

The adaptation of Trott's (1988) exercise to measure cervical short flexor endurance capacity is a time efficient and inexpensive tool that was shown to provide reproducible measurements one month apart. The short flexor endurance test was shown to be stable and, after taking account of the random subject effects, only small within-subject variations occurred between test and retest scores. A systematic improvement in mean endurance capacity occurred for both men and women. The improvement was significant for women, and non-significant for men. Measurer error, or a learning or treatment effect may have contributed to this improvement. Further studies are necessary to demonstrate the validity of the measure and to more fully investigate the reasons for systematic mean improvement.

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Measurement of Cervical Excursion Angles in a Treatment Setting

A Pilot Study

Karen Grimmer

Key Words

Linear movement, clinical measurement device, cervical posture, reliability.

Summary

Measurement of cervical posture in a treatment setting is frustrated by limited access to accurate equipment which is inexpensive and time-efficient. This paper describes a device which provides reproducible measurements of the linear movement occurring at the superior-most tip of the helix of the ear, and the spinous process of C7, during excursion movement of the head from a corrected position of chin retraction to the usual resting head position. Angles of excursion were computed from the linear measurements. The device is portable, inexpensive to manufacture and quick to use. The temporal stability and reliability of the measurements produced by this device suggest it would be useful in clinical settings for measuring change in cervical posture over time.

Introduction

The search for reliable methods of measuring human posture has stimulated many studies. One accepted method of estimating cervical resting posture involves inspection of the position of the head with respect to the gravitational axis (Kendall *et al*, 1952). However, the subjectivity of this method limits its usefulness both for repeated individual measures, and for determining the range of resting postures found within the population (Braun and Amundson, 1989).

Several objective methods have been used to measure the range of cervical resting posture. Expense, safety and/or time constraints have limited their application to mainly research settings. These methods include the range of movement of cervical joints (Kadir *et al*, 1981; White and Panjabi, 1990), X-ray techniques (Fielding, 1957; Kottke and Lester, 1958; Smidt *et al*, 1984; Van Mameren *et al*, 1990), measurements from photographs (Braun and Amundson, 1989; Loeb, 1967), and computer-assisted anatomical positioning (Gervais and Marino, 1983).

It has been established that the upper and lower aspects of the cervical spine describe different angles of movement in order to maintain the cervical lordosis (Penning, 1978; White and Panjabi, 1990). Although these studies have demonstrated wide variation in individual spinal joint movement, few data are available which explore the degree of upper and lower cervical excursion, occurring in the sagittal plane, as subjects move into their usual resting posture from a corrected position (Hanten *et al*, 1991). Although simple methods

of measuring the sagittal excursion of a single point on the cervical spine have been proposed by Rocabado (1983) and Hanten *et al* (1991), assessment of the differential movements of the upper and lower cervical spine will be enhanced by determining the linear movements of at least two body landmarks (Dalton, 1989; Lind *et al* 1989; Van Mameren *et al*, 1990; Vig *et al*, 1980).

While the concept of forward head posture (FHP) receives frequent reference in the literature on posture and pain, neither a standard definition nor an acceptable measure of FHP has been resolved (Ayub *et al*, 1984; Braun, 1991; Hanten *et al*, 1991; Passero *et al*, 1985; Raine and Twomey, 1992; Watson and Trott, 1991). The term FHP has been loosely used to describe a broad range of posture with the head resting anteriorly to the gravitational line (Cailliet, 1988; Kendall *et al*, 1952; Rocabado, 1983). More precisely, Jull (1988) refers to FHP as a poked chin posture occurring as a result of an extended upper cervical spine, and a flexed lower cervical spine. However, Hanten *et al* (1991) suggest that 'stating that someone has FHP based solely on resting head posture provides no information about the mobility in the excursion range'.

Excursion is defined in the physical sense by the *World Book Dictionary* (1974) as 'the departure of a body from its main position of proper course', and in the common usage sense as 'a short journey made with the intention of returning'. Given the philosophy of postural correction which underlies the physiotherapy management of posture-related disorders (Ayub *et al*, 1984; Janda, 1988; Trott, 1988), these definitions explain the need to measure the forward movement of the head relative to a fixed point. While photography using projected protractors quantifies the resting angle of the skull on the base of neck by measuring the angle of the tragus to C7 line from the horizontal (Braun and Amundson, 1989) it does not determine the amount of sagittal excursion which occurs during assumption of head resting posture. Thus, regardless of the cost, photography may not be as appropriate in assessing day-to-day change in cervical posture as the total head excursion concept of Hanten *et al* (1991).

The linear excursion measurement device (LEMD) was developed in a treatment setting as a means of providing serial measurements of sagittal excursion from a corrected position of maximal retraction of the chin to the usual resting head position. The development of this device was stimulated by the non-availability of a reliable but inexpensive means of measuring change in cervical posture in a clinical setting.

This paper details the results of a pilot study which describes the standard test procedure and evaluates the reliability and temporal stability of the measurements

taken by the LEMD. Given an assurance of consistent measurements, the LEMD offers a means of detecting and objectively recording change in cervical posture over time. Such measurements will assist in describing the range of head postures found in the population, and in quantifying the effectiveness of physiotherapy intervention for posture-related problems.

Method

Subjects

In order to study the temporal stability and reliability of the measurements taken by the LEMD, the pilot study was conducted on normal subjects — people whose cervical excursion movement was most likely to be consistent over time. Events considered to affect consistent cervical excursion movement were previous injury to the neck or back, altered hormonal activity occurring in pregnancy of breast feeding, and current use of analgesics, muscle relaxants or anti-inflammatory drugs. People were screened for these before enrolment into the study.

Twenty subjects who were able to attend measuring sessions on four consecutive days took part. In order to obtain this sample size, 23 people were randomly chosen from the local government electoral roll of the Huonville municipality in Tasmania, Australia. One person refused to participate, one person was pregnant and one person was taking non-steroidal anti-inflammatory drugs for arthritis of the knee. The remaining 20 complied with the enrolment criteria.

Description of the Device

The LEMD consists of a vertical backboard attached at right angles to a horizontal board seat. Two vertical slots are cut, one into the centre of the backboard, and one 15 cm to the right of this slot. A frame fitted parallel to each slot on the rear of the backboard accommodates a sliding bracket. A casing, mounted on to the T-square bracket, allows a calibrated steel ruler to run through the vertical slot. Each casing has two screws: one to lock the T-square bracket on to the frame, and the other to lock the ruler into position within the casing.

A millimetre ruler with a sliding central pointer is aligned parallel to each vertical slot on the rear of the backboard.

Anatomical Reference Points

The superior-most tip of the helix of the ear was chosen as an indicator of skull movement because it is clearly visible, moves in direct relation to the skull, and can be indelibly marked for re-measurement.

The spinous process of C7 was chosen as the other reference point because it can be located by sight and palpation, and represents the distal end of the cervical lever.

Test Procedure

The measurement device was positioned on an adjustable stool which allowed each subject to sit with thighs, knees and ankles at 90°. Subjects' forearms rested comfortably

on their thighs. The reference points at the top of the ear and the spinous process of C7 were marked.

Subjects then maximally retracted their chins, pressing the back of their head and their shoulder blades on to the vertical backboard. The maximal chin retraction position is described by Braun and Amundson (1989) and McKenzie (1983). Subjects were then asked to spot a letter, level with their horizontal gaze, on a wall chart in front of them. The horizontal rulers were then positioned at 90° to the anatomical reference points, and the position of the T-square was marked on the vertical ruler (fig 1).

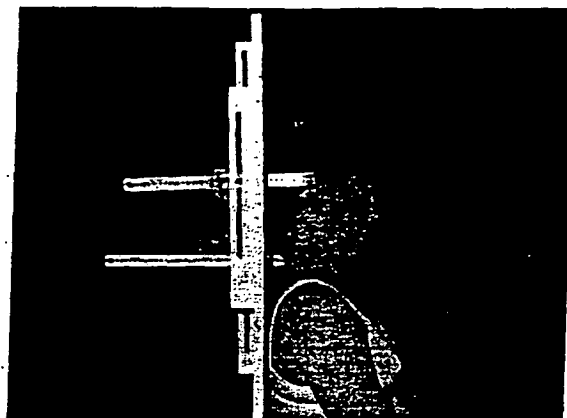


Fig 1: Maximum chin retraction position used as starting position for measurement of excursion movement

While a large range of chin retraction mobility was observed, positioning the back of their head and their shoulder blades on the vertical backboard standardised the starting position for all subjects.

Subjects then assumed their usual cervical resting posture using the technique described by Solow and Tallgren (1971). This consists of flexing and extending the cervical spine in three decreasing amplitude movements, until the usual resting posture of the head is obtained. Subjects maintained contact between their scapulae and the vertical backboard, and spotted the selected letter during each head sweep.

The usual resting posture was marked by sliding the T-squares down, and again fixing the horizontal rulers level with the marked anatomical points (fig 2).

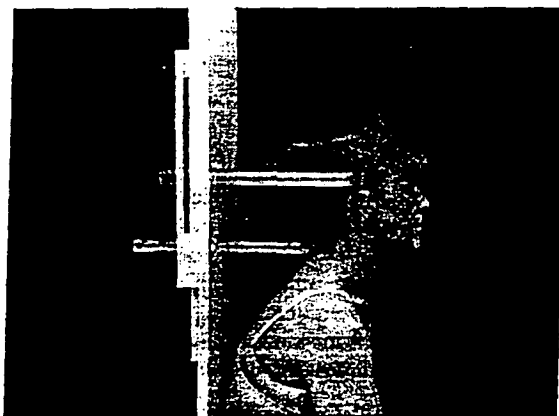


Fig 2: An example of a resting head position, from which second measurements are made

Test Re-test Procedure

The device was tested on four consecutive days in order to minimise potential postural variation associated with functional and emotional factors (Wägenhausen, 1971). However, the time of day of which the testing occurred could not be controlled. Four measurements enabled six paired comparisons to be made, giving greater opportunity to explore temporal stability and measurement reliability. The tester instructed all subjects, using a prepared protocol. She also read the linear measurements. The daily results were recorded by an independent assistant. Neither the subjects nor the tester viewed the test sheet at any stage during the test.

Measurements

1. Four measurements were taken at each test: the horizontal and vertical movements at the superior-most tip of the helix of the ear, and the horizontal and vertical movements at the spinous process of C7. The vertical distances through which the T-squares had travelled were read in millimetres (D1 and D3) from the vertical rulers beside each slot. The distance from the backboard to the superior-most tip of the helix of the ear (D2), and from the backboard to the centre of the C7 spinous process (D4) were measured in millimetres from the horizontal rulers.

2. Figure 3 illustrates the method of determining the excursion angles from the linear measurements. Illustrations are given of the starting position of the marked anatomical points (fig 3a), and two variations in resting head postures found in the study sample (fig 3b, 3c). By combining the vertical and horizontal measurements occurring at the superior-most tip of the

helix of the ear (D1 and D2) and at the spinous process of C7 (D3 and D4), the excursion angles at these anatomical points were calculated using the formula:

$$x' = \tan^{-1} \frac{\text{vertical distance}}{\text{horizontal distance}}$$

Analysis

Pearson's (ρ) statistics, standard error of the difference between correlated means, and p values from Student t -tests were used to compare paired tests. Account had to be taken of the correlation between paired tests (the same subjects measured under the same conditions). Because these were not independent samples, the standard error of the difference between the means was calculated according to the method described by Runyon and Haber (1972) and Snedecor and Cochran (1967). In the analysis, males and females were combined because the aim of the study was to determine the temporal stability and the reliability of the measurements produced by the LEMD.

Results

The Pearson's (ρ) statistics are reported for all paired test measurements in table 1. Statistical testing confirmed that the values obtained were high, and consistently high over all pairs.

Table 1: Pearson ρ for paired test results

Paired tests	1&2	1&3	1&4	2&3	2&4	3&4
Superior-most tip of helix of ear						
Vertical	0.96	0.97	0.95	0.93	0.93	0.97
Horizontal	0.87	0.89	0.89	0.87	0.92	0.95
Excursion angle	0.90	0.98	0.94	0.90	0.89	0.96
Spinous process of C7						
Vertical	0.96	0.94	0.90	0.91	0.88	0.97
Horizontal	0.85	0.85	0.79	0.95	0.93	0.91
Excursion angle	0.94	0.93	0.95	0.89	0.88	0.95

The mean and standard deviation of the linear measurements and excursion angles for each test are reported in table 2.

Table 2: Means (standard deviations) of linear movements (in centimetres), and the computed excursion angles (in degrees) produced by each test at the top of the ear, and at the spinous process of C7

Test	1	2	3	4
Superior-most tip of helix of ear				
Vertical (D1)	16.1 (9.4)	15.5 (9.2)	16.2 (9.8)	16.1 (9.8)
Horizontal (D2)	166.6 (17.2)	169.6 (19.8)	168.1 (17.4)	167.9 (15.4)
Excursion angle	5.5 (3.2)	5.2 (2.9)	5.5 (3.1)	5.5 (3.3)
Spinous process of C7				
Vertical (D3)	11.8 (7.2)	12.2 (6.3)	12.6 (7.6)	12.1 (6.2)
Horizontal (D4)	79.1 (14.1)	80.9 (18.9)	82.3 (19.3)	81.8 (17.8)
Excursion angle	8.5 (4.8)	8.6 (4.6)	8.7 (5.3)	8.4 (4.6)

When examining the difference between means, Snedecor and Cochran (1967) suggest that for repeated tests on

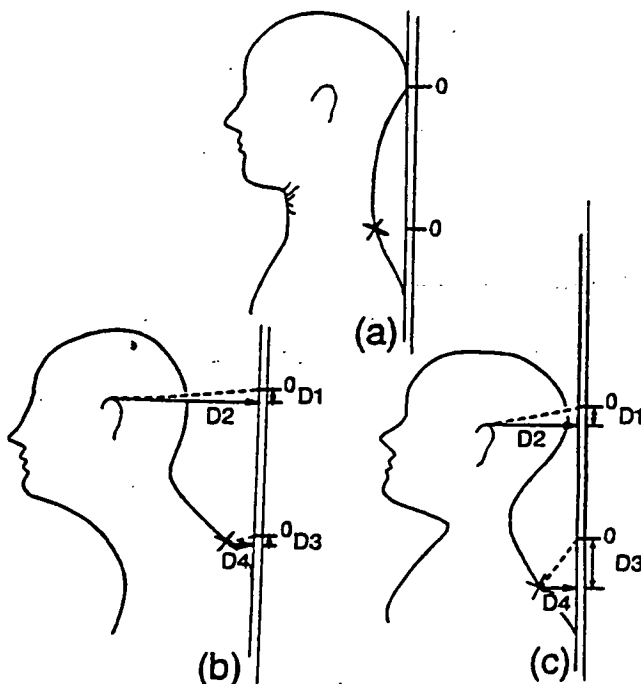


Fig 3: Illustration of the method of determining excursion angles. (a): Maximum chin retraction starting position. (b, c): Illustrations of two types of resting head positions found among the study subjects, the linear movement traced by each anatomical point, and the excursion angles calculated at each anatomical point

the same subjects, the difference between means should be ranked according to size, and significance tests conducted on the highest ranked pair first. If this pair is found to be not significantly different, there is confidence that the difference between all other paired means will be non-significant. This was found to be the case in this study for all linear measurements and excursion angles. In table 3, the highest ranked pair of tests for each measurement is indicated and the difference between the means is noted. The standard error between the all pairs of correlated means is reported. The p values for Student t-tests for all paired tests, regardless of ranked difference between the means, are also reported, in order to present the range of values found in the significance testing.

Table 3: Standard error of difference between all paired tests (SE), the largest difference between paired means for each measurement (LDM) and the p value from Student t-tests on all paired tests

Paired tests	1&2	1&3	1&4	2&3	2&4	3&4
Superior-most tip of helix of ear						
Vertical						
SE	0.65	0.54	0.54	0.81	0.81	0.54
LDM				0.7 mm		
p value	0.18	0.43	0.40	0.19	0.23	0.43
Horizontal						
SE	2.31	1.97	1.92	2.22	1.93	1.35
LDM	3.0 mm					
p value	0.09	0.20	0.24	0.30	0.18	0.47
Excursion angle						
SE	0.39	0.45	0.47	0.46	0.42	0.27
LDM	0.3°					
p value	0.22	0.40	0.50	0.21	0.29	0.30
Spinous process of C7						
Vertical						
SE	0.41	0.57	0.74	0.73	0.65	0.63
LDM		0.8 mm				
p value	0.21	0.08	0.33	0.24	0.46	0.21
Horizontal						
SE	2.32	2.41	2.57	1.74	1.56	1.92
LDM		3.2 mm				
p value	0.24	0.09	0.33	0.21	0.33	0.41
Excursion angle						
SE	0.38	0.45	0.33	0.54	0.50	0.39
LDM						0.3°
p value	0.42	0.33	0.38	0.42	0.34	0.23

The gender and age group profile of the study sample is shown in table 4.

Table 4: Sex and age group profile of study sample

Age group (years)	Female	Male
18-39	4	6
40-59	3	4
60+	2	1
Totals	9	11

Graphical representations of the correlation between the superior-most tip of the helix of the ear excursion angles at tests 1 and 2, and between the spinous process of C7 excursion angles at tests 1 and 2, are found in figures 4 and 5. These give a visual picture of the temporal stability of the measurements taken by the LEMD.

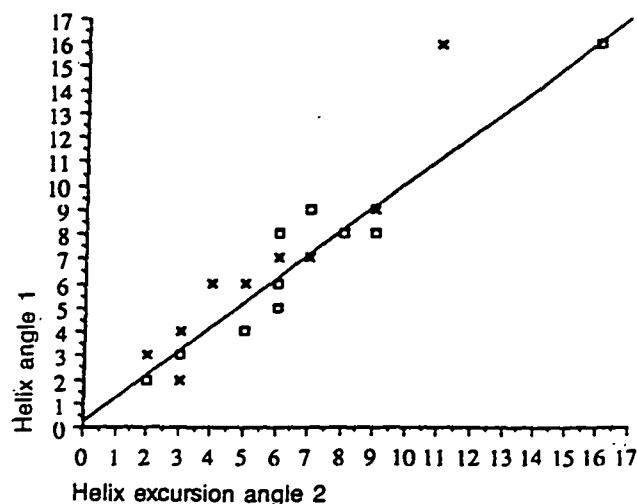


Fig 4: Graphical representation of temporal stability of the excursion measurement at helix of ear on tests 1 and 2

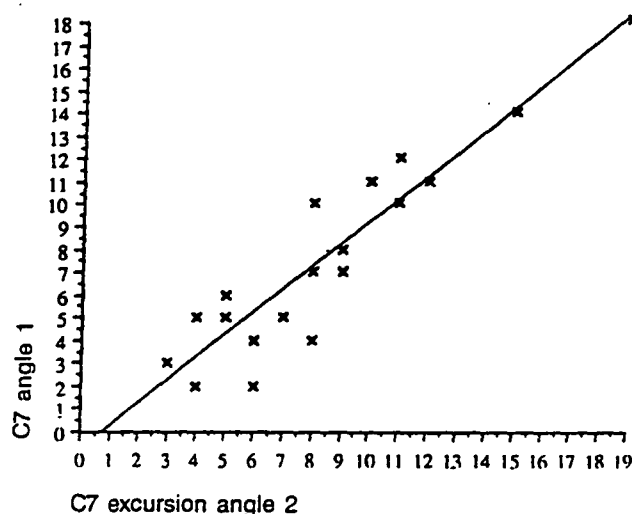


Fig 5: Graphical representation of temporal stability of the excursion measurement at the spinous process of C7 on tests 1 and 2

Discussion

The LEMD was designed as a low-cost, portable and reliable means of measuring the horizontal and vertical movements traced by the top of the ear, and the spinous process of C7, during excursion movement of the head, from the position of maximal chin retraction to its usual resting position. The measurements taken by this device are shown to be both stable and reliable.

The use of this device proved to be time-efficient. It took a maximum of five minutes to measure each individual, and record the results. The device cost less than A\$200 (£100) to manufacture.

Measurement of Excursion Angles

By acknowledging the effect of gravity on the behaviour of head posture (Basmajian, 1979; Wägenhausen, 1971), the device described in this study adds a vertical dimension to the Hanten *et al* (1991) methodology of horizontal excursion. Measurement of two linear movements at each anatomical point is a means of

quantifying the angles of movement traced by the head and neck, when relaxing from a corrected, chin retracted position to the position of usual head posture.

Standardisation of Procedure

A chest strap advocated by Braun and Amundson (1989) when obtaining cervical resting posture was not employed in this study. There was concern that it might disadvantage the true excursion movement of C7 by unduly constraining the usual relaxation of the lower cervical and upper thoracic spine. Mid-thoracic stability was confirmed by continued contact between the scapulae and the vertical backboard during all movements.

The Solow and Tallgren (1971) method, used in this study, of obtaining balanced resting head posture in a seated subject with a chest restraint, has previously been used by Dalton (1989) and Watson and Trott (1991). Because of the increased freedom of movement of the upper thoracic spine obtained in this study, without a chest restraint, it was found that all subjects achieved sufficient shoulder relaxation after the initial head flexion movement, to allow the head to lie anterior to the vertical backboard at the full arc of initial extension.

Given that head movement in the sagittal plane is associated with functional horizontal gaze orientation (Hanten *et al.*, 1990), the visual cueing employed in this study was thought to assist consistent horizontal head placement.

Temporal Stability and Reliability

The temporal stability of the measurements produced by this device is confirmed by the high correlation values between pairs of measurements which were taken at different points in time but within four days. The reliability of the results is shown by the absence of significant differences at the 5% level in the means of paired tests.

Conclusion

This pilot study suggests that the LEMD provides stable and reliable measurements of the horizontal and vertical linear movements which occur at selected anatomical points on the skull and the cervical spine in a normal population. The calculation of angles of excursion for these points allows the forward movement of the head to be plotted relative to a standardised starting position. The LEMD was found to be appropriate for use in the treatment setting because of cost, temporal stability, reliability, ease of use and time efficiency.

The concept of using postural excursion angles has not previously been recorded in the literature, and must be exposed to more rigid scrutiny before it becomes universally accepted as a measurement tool by physiotherapists. Such scrutiny would include further testing on a larger sample of normal subjects for inter-examiner reliability, as well as examining the LEMD's reliability in measuring serial excursion angles for subjects with cervical pain and/or dysfunction.

The excursion angles measured by the LEMD also need to be compared with other types of postural measurements such as the resting posture angle of Braun and Amundson (1989). Changes in posture as

a result of physiotherapy intervention may then be expressed in terms of the most useful measurement for demonstrating improvement.

Objective evidence of the success of physiotherapy intervention is increasingly necessary, given the financial pressures on health systems. Use of the LEMD may provide a particular advantage in clinical situations where fluctuating pain levels or postural abnormalities impede subjective assessment of treatment effectiveness. By enabling regular objective measurements of cervical posture to be recorded, treatment decisions can be more objectively reviewed. Feedback of improvement occurring with physiotherapy intervention will improve the communication between patient, physiotherapist, referrer and payer.

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Relationship between Occupation and Episodes of Headache That Match Cervical Origin Pain Patterns

Karen Grimmer, MMSc, B. Phty

The relationship between headache that matches cervical origin pain patterns, occupation, gender, age, and hours of work is examined in a randomly sampled, never-injured population. Although gender was established as a significant factor in the association between occupation and headache, age and hours of work were shown to have no effect. Women working in managerial and professional occupations had a significantly higher risk of cervical origin headache when compared with women working in either clerical or blue collar occupations. A similar association for men was not noted.

A belief has long been held that neck pain may be associated with specific occupational demands.¹⁻³ The strength of association between occupation and neck pain has not been confirmed⁴ because reports of the incidence of neck pain for specific occupations vary from 10% to 80%.⁵⁻⁹

Cervical origin headache is a symptom of dysfunction of the structures of the upper cervical spine.¹⁰⁻¹⁴ Frequently coupled with regular occurrence of neck pain and stiffness, cervical origin headache is also thought to result from repetitive postural and biomechanical stresses on the neck.^{12,14,15} Although recent cross-sectional studies have demonstrated a relationship between constrained working positions, static loading, and complaints of neck pain and stiffness,¹⁶⁻²⁰ work-related risk factors associated with headache of cervical origin have not been well researched.^{2,5,9,16,20-26}

Although both sedentary and heavy physical occupations are thought to involve a risk of neck strain,^{1,9,23,27,28} an examination of the relationship between occupation and symptoms resulting from dysfunction of the cervical spine has been frustrated by the lack of standard diagnosis criteria.^{7,21,28-30} For example, the difficulty experienced in classifying the symptoms associated with dysfunction of the cervical spine can be noted in the lack of specificity in the National Health Survey of the Australian Bureau of Statistics (1989 to 1990).³¹

In this cross-sectional study, a random sample of never-injured subjects is examined to determine the relationship between occupation and headaches that match established cervical

origin headache patterns. The effect of gender, age, and hours of work on the reported headaches is considered.

Methods

Subjects

Four hundred and fifty subjects were randomly selected from the electoral rolls of two adjoining Tasmanian municipalities and invited to join a study that examined the causality of cervical origin headache within the never injured population. Nine people declined to join the study.

Exclusion Factors

Exclusion for back or neck injury was made in an attempt to define a study group with no previous spinal injury, on the grounds that persons with neck or back injuries commonly report headache matching cervical origin headache pain patterns. Consideration of pregnancy, breast feeding, taking nonsteroidal antiinflammatory drugs, or analgesics excluded persons whose reports of pain may have been affected by hormonal activity or medication.³² In view of the ongoing debate regarding the overlap of tension and migraine headache symptoms,^{33,34} the identification of migraine sufferers³⁵ allowed exclusion of those subjects with known pain of a potentially different pathology. The exclusion factors used to screen the participants and the number of people excluded in each category are shown in Table 1.

TABLE 1
Exclusion Factors

Exclusion Factors	No. Subjects
Suffered previous neck injury	5
Pregnant or breast feeding	3
Using nonsteroidal Antiinflammatory drugs or analgesics for a musculoskeletal condition	4
Taking medication for migraine headaches (as defined by Ad Hoc Committee on Classification of Headaches 1962 ³⁵)	2
Total	14

Determination of Headache Status

The remaining 427 subjects were interviewed by this author to establish the frequency in the preceding month of headaches that matched the cervical origin pain patterns reported by Jull.¹⁵ The first seven of Jull's 10 criteria were used to identify cervical origin headaches in this study. These are:

1. The headache can affect any area of the head or face. It may be unilateral or bilateral.
2. Occipital or neck pain is a frequent accompaniment of headache.
3. The headache is commonly described as an ache of moderate severity, or as a feeling of tightness or heaviness in the head.
4. Headache is frequently accompanied by vascular or autonomic symptoms.
5. Patients commonly wake with headache.
6. Headache is usually associated with sustained neck postures, tension or neck pain and movement.
7. There is frequently a prolonged history of headache."

The last three of Jull's 10 criteria were not used in this study. These criteria are:

8. Neck trauma is commonly reported.
9. Standard x-rays usually display no abnormality.
10. Upper cervical joint signs are present."

They were not considered useful in determining the presence of cervical origin headache, because subjects with previous neck trauma had been excluded from the study to ensure a never-injured sample of the population, and neither roentgenogram nor manual examination of the cervical spine has been shown to definitively confirm the presence of cervical origin headaches in an uninjured study population.³⁶

In all subjects complaining of headaches of cervical origin, at least six of the seven criteria were found. The pain pattern not always reported was

criterion 4. Following the initial interview, all subjects were asked to keep a headache diary for the next calendar month. The first 100 subjects were then recalled, and their recorded headache frequency was compared with the recalled headache frequency. Ninety-three of the 100 subjects returned for the appointment.

Headache status was allocated to subjects who reported two or more episodes of cervical origin headache in the month preceding the study. This method of determining headache status has been reported previously.³⁷

Occupation

All subjects who were in paid employment in the three months preceding the interview were included in this study (417 of 427). Each subject's occupation was recorded using the Australian Standard Classification of Occupations (ASCO).³⁸ This method classifies individual occupations within broad occupational units that reflect similar types of work. These occupational units were used in this study because there were insufficient numbers in each occupation to draw any conclusions regarding individual occupational risk of headache. The ASCO occupation units³⁸ are listed in Table 2 along with all the individual occupations reported by the study subjects.

Age

In preliminary investigations, the Australian Bureau of Statistics³¹ age categories of young (up to 39 years), middle (40 to 59 years), and old age (60 years and over) groups was used.

Hours of Work

Subjects recorded their hours of paid work in the preceding 3 months, in four categories: full-time day worker, full-time night worker, part-time daytime worker, part-time shift worker.

Ninety-two percent of subjects were found to be working full time in daylight hours. These subjects were compared with the subjects working in all other hours of work categories for the purposes of multivariate logistic regression.

TABLE 2
Australian Standard Classification of Occupations Unit Codes³⁸ with the Occupations Reported by Study Subjects

1000: Managers and Administrators

Bank managers, small retail business operators, financial controllers, members of Parliament, government department administrators, hotel managers, farmer/owner/operators

2000: Professionals

Doctors, lawyers, accountants, teachers, physiotherapists, geologists, pharmacists, dentists, photographers, system analysts, librarians, journalists

3000: Paraprofessionals

Policemen, nurses, technicians, army personnel, local government officers, marine engineers, ambulance drivers and assistants, prison wardens

4000: Tradespersons

Carpenters, plumbers, mechanics, dressmakers, bakers, body shop technicians, electricians, painters, carpet layers, boilermakers/welders, roof tilers, bookbinders, butchers, greenskeepers, gardeners

5000: Clerks

Typists, telephonists, receptionists, bookkeepers, data entry personnel, computer operators, mail sorters, teachers' aides, postal clerks

6000: Salespersons and Personal Service Workers

Real estate agents, shop assistants, caregivers, travel consultants, hospitality industry workers, sales representatives, dental hygienists

7000: Plant and Machine Operators and Drivers

Bulldozer drivers, backhoe operators, crane drivers, truck drivers, excavator drivers, bus drivers, food processing machine operators

8000: Laborers and Related Workers

Farm workers, gardeners, factory workers, cleaners, fishermen, local government laborers, government department laborers, security guards, kitchen workers, furniture movers, garbage collectors

women reporting two or more headaches matching cervical origin criteria in the preceding month, in each of the young, middle, and old age groups. These results are reported, for interest, in Table 4. Overall, significantly more women than men reported headache status ($\chi^2 = 13.3$, $P = .0002$). The odds ratio comparing women with headache to men with headache was 1.53 (95% confidence limit, 0.94 to 2.41), significant at the 6% level. These results suggested that the analysis should consider men and women separately.

No significant effect of increasing age on headache prevalence was observed at this stage for either men or women. The odds ratios for headache across the three age groups for both men and women are described in Table 5. Given little evidence of an association between age and headaches, the age cutoff for the purposes of multivariate logistic regression was established at 40 years (that is, comparing young age with middle and old age). This demarcation has been previously noted as the time when degenerative changes to the cervical spine may become evident.^{9,42,43}

Occupation Examined in the ASCO Unit Codes

As was suggested by the results listed in Table 4, the incidence of headache status found in each of the ASCO occupation unit codes³⁸ was examined separately for women and men. These results are reported in Table 6. Although gender differences were observed for headache incidence in professional, paraprofessional,

Analysis

Epiinfo Version 5 was used to store the data and to conduct the univariate analyses. The Proc Logistic program in SAS³⁹ was used for the multivariate analysis because of the ordinal scaling of the response variable.

Results

Reliability of Headache Recall

The categories in which headache frequency was determined, the numbers in each category on initial interview and from their subsequent diaries, the percent agreement between the test/retest categories, the κ statistic,⁴⁰ the Spearman's ρ ⁴¹ and the χ^2 for trend are reported in Table 3.

Substantial agreement beyond chance between the test and retest results is suggested by these results. They establish not only the reliability

of retrospective reporting of this particular headache type, but also the temporal stability of the pain pattern criteria used to identify cervical origin headaches in this study.¹⁵

Gender and Age

Initial investigations determined the percentage of employed men and

TABLE 3
Results of Reliability Study for Headaches Matching Cervical Origin Pain Patterns¹⁵

Headache category	Recall	Diary	Agreement	κ^*	ρ	χ^2
Daily	6	4	66%	.58 ($P > .05$)	.78 ($P < .05$)	.53 ($P > .05$)
Every 2 days	4	1	25%			
Weekly	9	6	66%			
Twice a month	5	2	40%			
Monthly	12	8	66%			
Every few months	18	12	66%			
None	39	30	77%			
N _r	93	93				

* Critical value, .68.

TABLE 4

Percentage Designated as Having Headache Status (H/A) in Age Group/Sex Categories*

Age Group (y)	Women		Men	
	% H/A in Age Group	N _c	% H/A in Age Group	N _c
18-39	28%	98	20.5%	92
40-59	39%	71	24%	100
60+	40%	33	43%	56
N _T		202		215
Percentage of gender group with headache status				
	32%		23%	

* The number in each gender/age category is reported as N_c. The total gender number is reported as N_T.

TABLE 5

Odds ratios for headache for gender age groups*

Paired Age Groups	Female			Male		
	OR	95% CL	P	OR	95% CL	P
Young/middle	0.6	0.3-1.3	.2	0.9	0.4-1.9	.9
Young/old	1.0	0.4-2.5	.9	0.7	0.2-2.1	.6
Middle/old	1.6	0.6-4.0	.4	0.7	0.2-2.0	.7

* Exposure = pairs of age groups; disease = headache status/nonheadache status.

TABLE 6

Percentage of Men and Women with Headache Status in Each Occupation³⁷

Occupation (Code ³⁷)	Female		Male	
	N	% with H/A Status	N	% with H/A status
Manager (1000)	34	23.5%	49	26.5%
Professional (2000)	36	52.7%	17	11.7%
Paraprofessional (3000)	9	66.6%	9	44.4%
Tradesmen (4000)	10	20.0%	36	13.8%
Clerical (5000)	51	31.3%	14	21.4%
Service (6000)	11	9.1%	3	66.6%
Plant operators (7000)	9	0%	24	20.8%
Laborers (8000)	42	26.2%	63	26.9%
Total	202		215	

service, and plant operator occupations, the small numbers in these groups suggested that further investigations should be pursued to eliminate the possibility of chance occurrence.

Occupation Examined According to Occupational Demands

Larger numbers were obtained by regrouping the unit occupations into

three broad categories according to the perceived physical and mental effort expended during a working day.

Group 1 consisted of Managerial, Professional and Paraprofessional occupations (ASCO codes 1000, 2000 and 3000³⁸). These occupations were combined because of perceived mental stress and levels of light to moderate physical activity.

Group 2 consisted of Clerical and

Service workers (occupation codes 5000 and 6000³⁸). These occupations were combined because of low physical activity and the likelihood of repetitive activities and static postures.

Group 3 consisted of Tradesmen, Plant Operators, and Laborers (occupation codes 4000, 7000, and 8000³⁸). These occupations were combined because of observed levels of sustained heavy and/or repetitive physical activity.

Although this reclassification was not supported by any objective measurements of workload, subjects' perceptions of the activities that usually precipitated their headaches were recorded. The percentage of men and women who reported similar activities thought to be associated with headache is displayed for each broad occupational group in Table 7.

Stress was reported to precipitate headache by a high percentage of managerial and professional women. This group also reported the highest association between keyboard activities and headache.

Multiple Logistic Regression Modeling

To determine the nature of the variables that may be significantly associated with the model headache = occupation, a maximum multiple logistic model was constructed. This model examined the headaches reported by the managerial/professional group in relation to the headaches reported by the clerical and blue collar groups. This model was adjusted for hours of work, age, and gender. The saturated model⁴⁴ was not found to be significantly different from the maximum model, from observing the change in deviance (reported by -2 log likelihood). This indicated that inclusion of interaction terms in the maximum model was unnecessary.⁴⁴ Variables were then individually eliminated from the maximum model according to their impact on the model. The -2 log likelihood statistic and the residuals were examined at each step.

Although adjustment for age and hours of work was shown to have little impact on the model, distinctive pat-

TABLE 7

Activity Reported by Headache Sufferers as Most Frequently Associated with Headache Occurrence

	Group 1 (Man/Prof)		Group 2 (Clerical)		Group 3 (blue collar)	
	Female	Male	Female	Male	Female	Male
Keyboard activities	38.8%	25.2%	21.3%	23.1%	15.6%	16.5%
Reaching up activities	11.1%	12.5%	10.5%	0%	0%	7.4%
Looking down activities	25.0%	25.0%	10.5%	18.5%	23.1%	29.6%
Lifting	0%	0%	0%	0%	7.6%	18.1%
Stress	19.4%	0%	5.2%	0%	0%	7.4%
No known reason	5.7%	37.3%	52.5%	58.4%	53.7%	21.0%
N _H	33	19	17	5	14	28
N _T	79	75	62	17	61	123

N_H = the number of subjects with headache status in each broad occupational grouping; N_T = the total number in each broad occupation group, cited for comparison.

terms for men in the residuals corroborated initial indications that the association between headache and occupation should be examined separately for men and women. The results of the stepwise reduction of the maximum model are reported in Table 8.

TABLE 8

Likelihood Ratio Test Statistic for Sequential Models Applied to the Data

Sequence of Variables*	-2 log L (Deviance)	Diff	df	P
Saturated model**	467.56			
C Bc G A W	477.78	10.22	15	.80
C Bc G W	478.04	0.26	1	.61
C Bc G	478.43	0.39	1	.53

* C, clerical worker; Bc, blue collar worker; G, gender; A, age; W, hours of work.

Paired Multiple Logistic Regression

Pairs of broad occupational groups were subsequently examined, using multiple logistic regression, for gender-specific differences in the likelihood of headache occurrence. The crude and adjusted odds ratios (for age and hours of work) for each pair of broad occupational groupings are reported in Table 9.

Adjustment for age and hours of work produced, as expected, minimal effect on the association between occupation and headache of cervical origin. After adjustment, women in the managerial/professional group continue to display significantly higher risk of cervical origin headaches than do women in either the clerical/service occupations (odds ratio = 1.62, $P = .07$) or the blue collar occupations (odds ratio = 2.94, $P = .01$). The odds

ratios for men in each of the pairs of occupational groupings were not found to be significantly different.

Discussion

This study examined the hypothesis that occupation is associated with two or more episodes of cervical origin headache every month. There appears to be a significantly higher risk of cervical origin headache for women in managerial or professional occupations when compared with women in either the clerical or blue collar occupations. No such relationship is observed for men. Thus, whereas a model predicting headache by occupation appears useful for women, it does little to explain cervical origin headache incidence for men.

Adjusting for age and hours of work had little effect on the relationship between occupation and cervical origin headache for either men or women.

The strengths of the study are the random population sampling, the exclusion of subjects with previous injury to the neck, and the use of a pain pattern¹⁵ for defining cervical origin headache at interview. In addition, matching the recall of headache episodes with a pain diary for the following month verified recall reliability and confirmed the temporal stability of the cervical origin headache pain patterns.

The study sample was too small, however, to allow adequate exploration of individual occupational risk or of the effect of working hours on occupation demands and headache status. In addition, the cross-sectional nature of the work limits the conclusions that can be made. In particular, directionality^{45,46} cannot be determined from these results.

Previous work examining the incidence and causes of neck and shoulder problems have reported ambivalent findings with respect to occupational exposure.^{1,3,4,9,20,27} Although it has been suggested that occupations involving heavy loads on the shoulders protected subjects from neck pain,⁹ high odds ratios have been reported in meta-analysis for occupations with static loading on the neck and shoulders.²¹

TABLE 9

Gender-Specific Crude and Adjusted Log Odds Ratios for Each Pair of the Three Broad Occupational Groupings Adjusted for Age and Hours of Work

	Crude Odds Ratio			Adjusted Odds Ratio		
	OR	95% CL	P	OR	95% CL	P
Managerial/professional with clerical						
Female	1.89	0.6-3.85	.07	1.91	0.9-3.9	.07
Male	1.22	0.4-3.85	.7	1.37	0.6-3.0	.45
Managerial/Professional with blue collar						
Female	2.64	1.2-5.5	.01	2.94	1.3-6.6	.01
Male	1.25	0.6-2.4	.49	1.17	0.6-2.3	.64
Clerical with blue collar						
Female	1.39	0.6-3.1	.43	1.37	0.6-3.2	.45
Male	1.55	0.6-4.2	.44	1.64	0.5-5.2	.39

The combination of the eight ASCO³⁸ codes into three broader occupational categories to associate like physical and mental tasks provided larger numbers than were available for this study in the individual occupational codes. Although these three broad occupational groupings have not been noted in previous literature, Westerling and Jonsson⁹ and Hult^{1,6} discuss light and heavy jobs undertaken by sedentary and manual workers. The sedentary workers in these studies may include clerical, managerial, and professional people.

The literature suggests many predisposing factors for cervical origin headache. Muscle fatigue, biomechanical changes to the neck resulting from habitual head postures, poor body fitness, minimal sporting commitment, lack of sleep, high anxiety levels, and high levels of mental stress^{3,12,13,21,22,24} are all thought to be causally associated with cervical origin headaches.

This author has observed that the tasks undertaken by the managerial and professional group are unlike those undertaken by the clerical group. Examination of the activities that the headache status subjects believed were regularly associated with headache provides an indication of the different stresses that may be operational in the three occupational groups. These reports lend weight to the decision to regroup the occupations into three broader occupational groupings.

In view of this finding, cohort or case control studies, with more subjects and definitive physical and mental workload measurements, are indicated to explore further the directionality of the association between occupation and headache, as well as the reasons for gender and occupational differences in headache frequency.

The percentage of never-injured workers in this study who report two or more episodes of cervical origin headache a month seems high. Although there are few data with which to compare this figure, this finding could have ramifications for employers as well as researchers. Although the incidence of occupationally related headache may not be reflected

in time lost from work, further research is indicated into the effect of neck-based headache on job performance and the effect of the medication used to alleviate the headache.

Conclusion

In this study, women overall are shown to have significantly higher risk of cervical origin headaches than men.

Women in the managerial or professional groupings report significantly more cervical origin headache when compared with women in both clerical and blue collar occupational groups. Occupation is not associated with headache for men. Adjusting for age and hours of work has little effect on the odds of cervical origin headache for either men or women.

Combining the Australian Bureau of Statistics occupation codes into three categories of managerial/professional, clerical, and blue collar occupations provides valuable information with which to view occupational risk for regular episodes of cervical origin headache. Recategorizing these occupational units into three broad groups that reflect workload demands is supported by headache subjects' anecdotal observations of factors associated with cervical origin headache.

This study highlights the need for further research to determine why women in managerial or professional occupations appear to be more at risk for regular episodes of cervical origin headache than any other group.

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